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PRECAST CONCRETE PANELS FOR INDUSTRIAL ARCHITECTURE: KNOWLEDGE, UPGRADE AND TRANSFORMATION

PANNELLI PREFABBRICATI IN CALCESTRUZZO PER I GRANDI SPAZI DELLA PRODUZIONE: TRA CONOSCENZA, RIQUALIFICAZIONE E TRASFORMAZIONE

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SUMMARY

Le ricerche sugli spazi del lavoro e della produzione, a livello nazionale e internazionale, evidenziano alcuni temi generali di particolare interesse: lo scenario attuale delle aree dismesse, del riuso e del recupero degli opifici, le problematiche del degrado e del ciclo di vita delle costruzioni, l'attenzione al patrimonio industriale come oggetto di conservazione e valorizzazione. La ricerca di dottorato si è sviluppata attorno a questi temi con l'obiettivo di approfondirli rispetto al caso significativo dei grandi spazi produttivi realizzati con l'uso di pannelli prefabbricati in calcestruzzo, concentrandosi sull'architettura industriale che in Italia, tra gli anni '50 e '80, ha rappresentato la maggiore occasione di sperimentazione della prefabbricazione per progettisti e costruttori, con esiti talvolta notevoli e oggi oggetto di attenzione e tutela.

La conoscenza di questo patrimonio edilizio del passato recente implica una riflessione - tra architettura e tecnologia - sull'origine, l'evoluzione e le problematiche legate all'uso dei sistemi costruttivi in calcestruzzo per i 'grandi spazi' industriali. La comprensione di tali dinamiche permette, parallelamente, l'identificazione delle emergenze, intese come quelle opere di particolare valore e significato, meritevoli di tutela e che possono assumere un ruolo centrale nel processo di ri-disegno del territorio. Gli edifici della produzione devono, infatti, sempre più spesso trovare nuovi usi, in una prospettiva di riuso e rifunzionalizzazione attraverso un processo di trasformazione che sia coerente con valori, vincoli e criticità specifiche.

La prima parte della ricerca affronta il problema della conoscenza del particolare patrimonio edilizio oggetto di studio, concentrandosi, all'interno del panorama dell'architettura industriale del secondo Novecento, sui casi più significativi dell'uso di elementi prefabbricati in c.a. per l'involucro edilizio.

Questa indagine porta, come principale risultato, alla realizzazione di un catalogo, nella forma di database e sito web, sull'*Architettura industriale in calcestruzzo in Italia, 1950-1980*. Il database costituisce uno strumento per l'inquadramento e la documentazione del fenomeno dell'architettura industriale in Italia, implementabile e aperto all'approfondimento degli aspetti tecnico-costruttivi nonché delle tematiche di conservazione, riqualificazione e trasformazione. Il catalogo raccoglie una serie di architetture industriali significative del periodo individuato e include l'analisi di alcuni degli esempi più notevoli di edifici industriali prefabbricati.

La seconda parte della ricerca riguarda l'approfondimento degli aspetti qualitativi e prestazionali dell'edilizia industriale. Da un lato emergono le problematiche della tutela e della conservazione del patrimonio industriale moderno e contemporaneo e, dall'altro, le prospettive per il riuso e l'adeguamento agli attuali requisiti. In questo senso gli edifici industriali realizzati con sistemi prefabbricati rappresentano un campione significativo del patrimonio edilizio del Paese, che necessita di riqualificazione e *upgrade*, tenendo conto di aspetti architettonici, strutturali ed energetico-ambientali. Particolare attenzione è rivolta alle tematiche legate alla qualità ambientale e, avendo come primo riferimento il contesto regionale del Friuli Venezia Giulia, è stato possibile definire un quadro generale sulle possibili metodologie di valutazione e strategie di riqualificazione per gli edifici produttivi.

L'ultima parte della ricerca è dedicata agli aspetti progettuali legati alla trasformazione degli edifici industriali, con un'indagine sulla forma e sull'involucro, declinata rispetto a un'architettura significativa: lo stabilimento Sèleco, costruito alla fine degli anni '60 su progetto dell'arch. Gino Valle per le Industrie Zanussi a Pordenone e caratterizzato da un inedito sistema di facciata, che lo distingue come caso emblematico nel contesto dell'architettura prefabbricata per l'industria. L'ipotesi di riuso e rifunzionalizzazione dell'edificio è l'occasione per l'elaborazione di proposte per la riqualificazione e la trasformazione dell'involucro, con attenzione agli aspetti di conservazione, adeguamento funzionale e riqualificazione energetica nel rispetto dei valori formali e architettonici che connotano l'opera.
In accordo con i temi affrontati dalla ricerca, l'edificio oggetto di studio presenta elementi di interesse rispetto all'esperienza italiana sull'architettura industriale, capace di coniugare le tecniche e i sistemi costruttivi della prefabbricazione in calcestruzzo con la ricerca estetica e architettonica orientata alla sperimentazione, alla declinazione di un linguaggio architettonico moderno e all'espressione dell'immagine aziendale. Nell'attuale contesto di mutamento dei luoghi legati all'industria, questi aspetti hanno, da un lato, orientato le politiche verso la tutela, dall'altro, posto nuovi interrogativi sulle prospettive di riuso e trasformazione dei manufatti. La formulazione di proposte per il caso di studio è intesa, in tal senso, come applicazione di un approccio e di una serie di soluzioni che siano esportabili anche ad altre costruzioni della tipologia oggetto di indagine.

SUMMARY

Research on industrial spaces at national and international level highlights some general topics of particular interest: the current scenario of brownfield sites, the reuse and renovation of factories, the issues of degradation and of the life cycle of building, the focus on industrial heritage as a subject of conservation and valorisation.
The study is developed around these topics, aimed at examining them as regards the large industrial spaces made with the use of prefabricated concrete panels, focusing on the industrial architecture that, in Italy, between the ‘50s and ‘80s, represented the greatest occasion to experiment with prefabrication for designers and construction companies, often leading to notable outcomes, which are now objects of studies and protection.
The knowledge of this heritage from the recent past start from the analysis and documentation - between architecture and technology - of the evolution and the current issues related to the use of precast concrete building systems for ‘large spaces’. The understanding of those dynamics allow to identify emergent architecture, meant as works of special values and meanings, which are worthy protection and may assume a central role in the redesign of the territory. In an industrial territory which continuously changes, these production spaces have to find new uses, in a perspective of reuse and renovation through a transformation process which must be respectful of values, restrictions and specific issues.

The first phase of the research involves the issue of the knowledge of this particular built heritage, focusing - within the wide context of industrial architecture from the late twentieth century, on the most significant examples of the use of precast concrete panels for the building envelope.
This investigation lead to the creation - as the main outcome - of a catalogue, in the form of a database and a website, about *Concrete industrial architecture in Italy 1950-1980*. The database is conceived as a tool for contextualising, documenting and evaluating the phenomenon of prefabricated industrial architecture in Italy; it could be extended and favours the analysis of technical aspects as well as issues of preservation, upgrade and transformation. The catalogue consists of a collection of industrial architectures characteristic of the period and includes detailed information about relevant prefabricated buildings.

The second phase of the study involves the examination of the aspects related to quality and performance of industrial buildings.
On the one hand, the issue of protection and preservation of the modern and contemporary industrial heritage emerges; on the other hand, the possibilities for reusing and upgrading it to current requirements are considered. In this sense, prefabricated industrial building are a significant sample of the Italian industrial building stock, which requires upgrade and refurbishment, considering specific architectural features as well as functional, structural, and environmental aspects. The study has focused especially on the issues of environmental quality and, taking into account the regional area, a general framework on the possible methodologies of assessment and strategies of energy retrofit has been discussed.

In the final and third phase the study addresses the design aspects related to the transformation of industrial spaces, with an investigation on the form and the building envelope implemented for a significant piece of architecture: the Seleco building, designed in the ‘60s by the architect Gino Valle for the Zanussi Industries and characterised by an original façade system, which connoted it as a significant case in the context of prefabricated architecture for industry. The purpose of reuse and refurbishment of the building become thus the opportunity for proposing upgrade and transformation solutions for the building envelope, taking into account the issues of conservation, functional upgrade and energy retrofit, however respecting the formal and architectural values of the work.
As regards the topics addressed by the study, the case-study building shows many elements of interest related to the Italian building tradition for industrial architecture, which combined the techniques and building systems of precast concrete with an aesthetic and architectural research oriented to experimentation, aesthetic and architectural approach oriented towards experimentation, modern architectural languages and the expression of the corporate identity through the workplace.
In the current changing context of the spaces linked to the industry, these aspects have, on the one hand, directed policies towards the protection, and, on the other, pointed out new issues regarding the reuse and transformation of buildings. The development of proposals for the case-study is intended, in this sense, as the application of an approach and a series of solutions that are also portable to other buildings of the type under investigation.

CONTENTS

INTRODUCTION

The study of evolution of the building techniques from the recent past is an important piece of knowledge and is essential for the understanding, the documentation and the transfer of that information, as reflected in a number of research programmes at European and national level - especially on the theme of cultural heritage.
Prefabricated building systems spread during the twentieth century, inspiring also architecture to embrace the concept of industrial and serial production, leading to significant outcomes according to the technological advances and, especially, the vision of architects and engineers. The history of prefabrication was characterised by the development of prefabricated system based on specific materials and techniques and in Italy concrete prefabrication evolved through history, architecture and design, to find its major scope in the industrial building sector.
The use of precast concrete panels for the construction of large industrial spaces is however a topic which has been only marginally investigated by research at national level. Relevant research studies on prefabrication in the Italian context, in fact, focuses mainly on the building systems for the industrialised housing sector, investigating the spread of concrete prefabricated systems according to the evolution of the twentieth century construction techniques or specific phenomena such as the ‘Italian prefabrication’ for residential construction or structural engineering works[1].
Nevertheless, the role of concrete prefabrication in the Italian construction sector is well-established in literature. In Italy the development of building industrialisation for the residential sector was about two decades later than in other European countries and, concurrently, a ‘prefabrication made in Italy' was developed, being based on prefabricated concrete skeleton systems and being used especially for the non-residential constructions. In this sense, as discussed in this study, building industrialisation and standardisation of components offered to different groups of designers the opportunity to explore new architectural languages, especially in industrial architecture.
Furthermore, research into twentieth century architecture has become increasingly central in the field of study, as demonstrated by the many initiatives for the documentation and transmission of knowledge about modern and contemporary architecture and the activities for the conservation and promotion of existing

[1] The research project coordinated by Sergio Poretti and Tor Vergata University of Rome “La costruzione industrializzata in Italia tra gli anni '60 e gli anni '80. Modi e tecniche di conservazione e recupero”, PRIN 2008; the research project coordinated by Carlo Olmo at Politecnico di Torino, “La concezione strutturale. Ingegneria e architettura in Italia negli anni cinquanta e sessanta: una ricerca multidisciplinare”, PRIN 2008; and the research “SIXXI: XX Century Structural Engineering: the Italian contribution”, ERC Grant 2011.

architectural assets[2]. Additionally, the growing awareness of the issues of protection and redevelopment of industrial heritage has oriented the study specifically to industrial architecture, considering its historical evolution as well as the current post-industrial situation. In this sense much research is focussing on the theme of conservation, renovation and promotion of industrial buildings and sites at national level[3]. The critical investigation on the spread of the different building systems highlights the prevalence of prefabricated types and their relevance as regards the need for conservation and upgrade of the Italian industrial building stock. In fact the main features of this building types - such as the low costs of design and construction - which have favoured their spread since the late twentieth century, today determine the major problems in terms of degradation, energy performance and upgrade strategies.

In this context, other main topics related to the upgrade and reuse of industrial buildings also have emerged: the questions about the future use of existing industrial sites are accompanied by functional, structural and environmental considerations. The specific seismic vulnerabilities, the sustainability aspects, and the protection and conservation issues have especially inspired many studies, aimed at defining proper assessment methodologies or standard and guidelines for the intervention, following the main themes proposed by the European Commission.

All these consideration highlight the importance of a specific approach towards industrial architecture and its upgrade, attentive to values, restrictions and specific issues, especially in an industrial territory which is ever changing and in which these industrial spaces need new uses.

OBJECTIVES

The study addressed the above-mentioned topics, focusing on the use of precast concrete panels for the building envelope of large industrial spaces in Italy, considering the national context but without neglecting the necessary links with the European and American ones. The three main themes investigated, as reflected in the contents structure of the thesis, are: *i.* the knowledge and documentation, considering the historical context as well as the design principles involved in the construction of prefabricated industrial buildings, *ii.* the issues of preservation and upgrade of the industrial architectural assets, *iii.* the reuse and transformation strategies for prefabricated industrial architecture.

[2] As demonstrade by the activity of Docomomo International and Italy, by research carried out by École Polytechnique Fédérale de Lausanne and by funding initiatives under the “Reflective societies” programme of Horizon2020.

[3] The research project “RE-CYCLE Italy. Nuovi cicli di vita per architetture e infrastrutture della città e del paesaggio”, coordinated by Renato Bocchi at IUAV University of Venice.

As regards the historical context and the design principles of prefabrication in the wide architectural production of the last century, the investigation considered the main developments of construction techniques and their relationship with the debate on prefabrication and building industrialisation, in order to define their historical relevance and to identify emergent examples of prefabricated industrial architecture. As prefabrication emerged from the process of rationalisation of the construction which characterises the post-war years, the basic concepts of modular coordination, unification and component design were considered. Concurrently, the technological and structural solutions used for the construction of ‘large spaces’ have been addressed with attention to the specific connotations of precast concrete.

With respect to conservation and upgrade issues, the study took into account both the cultural and physical aspects regarding existing industrial buildings. The current approaches for the protection and promotion of industrial heritage were presented, highlighting the current problems regarding the preservation of contemporary architecture such as prefabricated buildings. Moreover, the general material, structural and environmental aspects were considered in order to discuss the specific vulnerabilities of precast concrete panels related to concrete degradation, seismic behaviour, and energy performance.

Finally, the study addressed the wide theme of the transformation of industrial heritage, and industrial buildings from the recent past in particular. The discussion of strategies for reusing and adapting industrial spaces to new uses and current requirements was aimed at defining a reference framework for the intervention.

METHODS

The study was developed taking into account the themes and methods of the academic disciplines ICAR/10 Architetural Engineering and ICAR/14 Architectural and Urban Design. The discussion has initially considered the analysis of the building structures in their constructional, functional, typological and formal aspects, the critical evaluation of the building techniques and their implementation in design and production processes, and the problems relating to the restoration and renovation of the existing assets. Then the methodologies of the field of design were applied in the discussion of the aspects of renovation and transformation of existing buildings. The link between architecture and techniques, which characterised also the development and evolution of this particular prefabricated architectural heritage, thus became a fundamental element of the approach adopted in the study.

The research activity was organised in three main phases - corresponding to the duration of the Ph.D. Course: a first one dedicated to the documentation and investigation, a second one on the assessment, and the third one on the design and transformation solutions.

In detail, the first phase, the theme of the knowledge and documentation of this special industrial heritage was developed in accordance with current research approaches, following the example of recent studies into modern and contemporary architectural heritage. The research activity involved a comprehensive literature review on the topic, the identification of significant buildings and authors and the production of a catalogue of concrete industrial architecture in Italy in the form of an online database.

The second phase consisted in the discussion of the aspects of quality and performance degradation of industrial buildings. A special attention was paid to the issues of energy performance and environmental sustainability, thanks to a research and study internship at the Regional Agency for Sustainable Building of Friuli Venzia Giulia (ARES-FVG). The theme of protection of industrial heritage was also investigated during an internship period at the local Superintendence (SABAP).

Finally the third phase the study addressed the design aspects as regards the current approaches to the transformation of industrial spaces. The investigation on the form and the building envelope was implemented for a significant piece of architecture - the Sèleco building, designed in the ‘60s by the architect Gino Valle for the Zanussi Industries -. Upgrade and transformation solutions were proposed for the building envelope, considering the issues of conservation, functional upgrade and energy retrofit and respecting the formal and architectural values of the work. These solutions for the case study were to be understood, in this sense, as the application of an approach which could be also portable to other buildings of the type under investigation.

1 PREFABRICATED SYSTEMS AND PRECAST CONCRETE FOR INDUSTRIAL BUILDINGS IN ITALY: PREVALENCE, FEATURES AND CURRENT CONDITION

1.1 Prefabricated systems and precast concrete panels for industrial buildings in Italy

During the twentieth century, research into the rationalisation of constructions inspired architecture too to embrace the concept of industrial and serial production, leading to significant outcomes, permitted by the technological advances and, especially, the vision of architects and engineers.
However, the history of prefabrication was characterised by the development of prefabricated systems based on specific materials and techniques. Concrete prefabrication evolved through history, architecture and design and, in Italy, finds its principal use in the industrial building sector (paragraph 1.1.1).
Concurrently, the industrial building type evolved according to the technological progresses and particularly with the implementation of prefabricated building systems, with which a series of precast concrete elements specific for industrial construction were gradually introduced - pillars, beams, slabs, façade panels and finishing components (paragraph 1.1.2). In this sense, the remarkable amount of prefabricated industrial building in Italy has been and is characterised by a specific typology of building envelopes, made with precast concrete panels, which also define the industrial landscape of the country. Thus, in the following paragraphs, the study will address the evolution of concrete prefabrication, focussing on these façade elements and aiming to provide a useful background for the discussion on the issues of preservation and transformation in the further chapters.

1.1.1 Concrete prefabrication through history, architecture and design

A necessary distinction between industrialisation and prefabrication favours the discussion of the development of both prefabricated systems and precast concrete components through history, architecture and design. Prefabrication is defined as the practice of assembling the components of a structure in a factory or other manufacturing site. While *industrialisation of building* is meant as the generic application of industrial methodologies in the construction sector, through a transition to a rational approach to the building process, *prefabrication* may refer to the generic production off-site of building elements. In Italian, the word *prefabricated* means, in fact, the building components previously produced in a place other than the building

site, but the building made by the assembly of prefabricated components is also called *prefab*.
On the other hand, prefabrication is an essential tool of industrialised processes but does not imply the exclusive use of them, and indeed, the first examples of prefabrication anticipated the advent of industry. While all building systems include the preceding production of building elements whether on-site or off-site, the category of prefabrication includes all systemised off-site manufacturing of components and elements (although sometimes the elements are pre-fabricated on-site); prefabricated systems, however, mainly consist of manufactured components and the use of industrial methods of assembly is also a common feature.

The principles of mass-production promoted by Henry Ford in the early years of the twentieth century inspired architecture too to embrace the concept of industrial and serial production. In those years, in fact, interest in prefabrication was aroused and a number of theorists, architects and constructors became committed to standardisation and prefabrication.
Le Corbusier introduced the idea of the house as *a machine for living in*, and with his project for the “Maison Domino System” and “Maison Citrohan” he referred to the dream of the mass production of a house type. In 1960, Reyner Banham (1922-1988) wrote “Theory and design in the first machine age”, coining the term *first machine age,* which covers the early twentieth century, when manufactured products were inspiring the *machine aesthetics*, which characterised the theoretical and architectural work of the architects of the Modern Movement. Later Martin Pawley (1938-2008) coined the term *the second machine age* for the '60s, when a new awareness of machine aesthetics as a conscious stylisation of industrial products grew, while the industrialisation of architecture did not. In fact, during the last century, visionary experiments in building systems gained much attention, but the novelty of industrialisation wore off relatively quickly in many sectors of architecture (Knaack *et al.*, 2012).

Prefabricated systems, like other systems of building and the subsequent variety of architectural forms, took their cues from cultures, geography and its natural resources, technological advances and, especially, the vision of architects and engineers. Thus prefabricated construction developed and spread through different countries (mainly in the USA and Europe), with local variations resulting from the availability of materials and prevailing construction techniques. Moreover, the evolution of prefabrication was mainly related to the economic and social conditions of the countries in which it took place, especially in relation to innovative drives by industry and demands from the community due to particular circumstances (Frateili, 1966), such as housing shortages, post-war reconstruction or the development of the industrial sector.

As regards the origin of prefabrication, in the era when the cast-iron architecture developed to its peak, the building of the Crystal Palace by Joseph Paxton (in 1851) was an early example of industrialised construction and also paradigmatic of prefabrication at component level. Soon later, the Biarritz Casinò by Edmont Coignet (in 1892), built with precast on-site structural elements, became a model of prefabrication of concrete.

These two masterpieces might also be considered as early examples of the two main categories of prefabricated systems, which were later defined as *light prefabrication*, based on steel, wood and other lightweight materials, and *heavy prefabrication*, based on large concrete units. Even though the second category is the main focus of this study, the two are both considered as the fundamental prefabricated systems which developed in parallel throughout history of prefabrication.

The evolution of prefabricated systems and precast concrete in the twentieth century

At the beginning of the last century, with the spread of reinforced concrete, the first experiments in pre-industrial prefabrication were carried out both in America and Europe.

In the USA, even though prefabricated systems were mainly based on timber and cast-iron construction, relevant experiments with precast concrete started in the first years of the twentieth century. Shortly after Hennebique's patent in France, Beardseley devised a concrete panel[4] with metal frame and reinforcing mesh (in 1900), which is therefore one of the first examples of precast concrete wall panels (F. 1-1, F. 1-2)[5].

Although in the USA the development of precast panels really began in the second decade of the twentieth century, precast panels were seen also as early as 1875 when Lascelles patented his system for reinforced precast construction, which included precast slabs. Other precast concrete panels system were also patented in the USA in those years, such as the “Ransome Unit System” (in 1911), which included precast wall panels[6].

In the same period in Europe, prefabricated concrete slabs, beams and trusses were introduced by Siegwart, Corradini and Visintini (in 1901), Franck patented a system of panels made of cement-asbestos (in 1908) and Mannesmann introduced a building system for multi-storey building based on concrete panels (in 1909), while Edison

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[4] The “Building-panel” was patented by Henry W Beardsley in 1900 (patent US 675648 A 1901). It was described as an improved panel for use in the construction of temporary and permanent buildings, aimed at simplifying and facilitating building construction of walls, partitions, floors, ceilings, and roof. The panel consists of a frame of metal or wood having wires secured across it and being filled with cement (or plaster or other cast materials). The patent illustrates also the combinability of panels.

[5] Josef Monnier had already devised an iron-reinforced cement panel for building façades in 1869.

[6] The historic evolution of precast concrete architectural components in the USA is widely discussed in recent studies (Cellini, 2008; Meloy, 2016).

carried out his famous experiment for the house realised with a single casting (in 1908).

In the 1910s the most relevant work was carried out by Conzelmann, with more than fifty patents for his concrete “Unit System” (between 1910 and 1916), while in the USA Atterbury designed his large hollow panels (which were later used for the Forest Hill house in 1918). Shortly after the World War II, several types of prefabricated homes were developed in Great Britain, such as the “Dorlonco Houses” and the “Weir Houses”.

In this climate, notable architects also put their efforts into industrialisation and prefabrication of concrete construction[7]: Le Corbusier conceived the “Maison Domino” system (in 1914, first construction in 1929), and Wright designed the “Textile Block” system (firstly applied in 1914-1915 for the Midway Gardens and the Albert German warehouse).

During the '20s and the '30s, the concepts of <u>functionalism and mass production</u> of buildings were mainly implemented in residential building, being related to <u>housing programmes in various countries</u>. However, although many architects proposed programmes and prototypes, the idea of prefabricated homes did not take off immediately due to a negative opinions regarding serial building, which also deterred the industrialisation of architecture (for many years, in many countries).

The first industrialised housing programmes developed in the USA during the housing boom in the '20s and '30s: balloon-framed houses, based on American traditional timber construction, were industrialised, standardised and systemised, and then even sold through mail-order catalogues. In the same period, building systems based on cast-iron also developed, and mass-produced cast-iron beams, columns and façades spread across the country, embracing the styles originating from Europe.

In Europe, even though prefabrication was not new and can be found in wooden military structures, corrugated metal churches in the colonies and factories built of cast-iron (Knaack *et al.*, 2012), prefabricated architecture developed its own modern architectural language through the experimentation of architects of the Modern Movement. It is no coincidence that the most influential school of art and architecture in the twentieth century, the Bauhaus, experimented with new architectural forms for industrial production.

In Great Britain, the development of industrialised building had started before World War I to provide factory-made dwellings and other facilities for the colonies in Asia and Africa (and even before for the American continent). Besides, after the war, the shortage of skilled labour and traditional building materials also favoured the introduction of alternative building techniques. Many new experimental building

[7] Morris A. E. J. traces the development of the architectural use of precast concrete from the re-discovery of concrete in the early 19th century to the awareness of the potential of precast concrete for mass production of the ‘70s in (Morris, 1978).

systems were proposed; they were based on concrete frames or concrete blocks, for instance Airey's “Duo Slab” concrete system (F. 1-5)[8].

In Germany, experiments in concrete slab construction were started in the '20s to solve the housing shortages caused by the First World War. The same system (“System Occident” by Martin Wagner, 1924-1926) was later adapted by Grosvenor Atterbury in the USA (F. 1-3). In the “System Occident” the slabs were 11 m x 4 m large and only 25 cm thick, the formwork and erection techniques of the double-storey concrete slabs was based on the 'tilt-up' technique[9]: the slabs were prefabricated on-site an then lifted, rotating, in their actual vertical position[10]. Ernst May, reinterpreting the Atterbury method, devised the Frankfurt Slab System (Frankfurter Plattenbau, 1926-1930) for houses: the slabs were 3 m x 1.2 m large and 20 cm thick, handled with smaller rotating cranes and manufactured off-site, in the factory (F. 1-4, F. 1-6).

At the Bauhaus, the “honeycomb” construction method was developed to build the Dessau-Törten suburban estate (Walter Gropius in 1926). Originally designed as a modular system of standardised formwork, clustered in groups of four to twelve units and then poured with concrete, the final version consists of walls of prefabricated hollow-core slag-concrete blocks and ceilings of reinforced concrete beams, produced on-site (Knaack *et al.*, 2012).

The Weissenhofsiedlung estate was presented at “Die Wohnung” exhibition in 1927 with model houses designed by many architects of the Modern Movement; even though the majority of the houses were constructed with wood/steel frames and prefabricated lightweight panels (F. 1-11, F. 1-12), some of the houses used variations of the Ernst May's concrete slab system.

Other remarkable examples of early prefabricated constructions based on concrete were the “Round house” in Dessau by Fieger (in 1923) with a steel or concrete structure, the “El Pueblo Ribera Court” in La Jolla by Schindler (in 1923) with modular formworks (F. 1-13, F. 1-14), the “Diatom House” series by Neutra (in 1925) with its special precast concrete panels[11], the “Minimal system” by Le Corbusier (in 1925), and the “Textile block system” by Wright (F. 1-15, F. 1-16)[12].

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[8] The prefabricated concrete wall systems adopted in GB between the ‘20s and the ‘40s, especially the Boot house and the Airey house, were known also in Italy (Griffini, 1949).

[9] The “tilt-up” method, also known as “tilt-slab” and “tilt-wall” was developed in the USA in the first years of the twentieth century (first patent in 1908) as a technique for prefabricating concrete wall elements - even entire walls - on the ground or the building floor, which served as a temporary concrete casting surface. It gained widespread use in the USA after World War II, when it was known also in Italy (Griffini, 1949).

[10] Even though the assembly system proved difficult and uneconomical due to the need of larger cranes to lift the large concrete elements and the fact that the pre-planned designs did not accommodate the large inaccuracies of the drying process this the System Occident was an important precedent for future slab systems, as discussed in (Knaack *et al.*, 2012).

[11] The details on the use of concrete in this and other significant modern buildings are included in (Ford, 2003; Blundell Jones and Canniffe, 2007).

[12] A first version of the *textile block* appeared in the Midway Gardens, and then the blocks were used between 1920 and 1925 for the houses in California: the Millard House (La Miniatura, 1923), Samuel Freeman House (1923), Storer House (1923) and Ennis House (1924).

In this period many other precast concrete systems and components were introduced: the T-stone system based on precast T elements (in 1930), the Maison Fregoli system by Beaudouin and Lods (in 1930), the concrete elements for ceilings in Italy (Travetto Varese in 1931), façade panels in r.c. for the "Cité de la Muette" by Beaudoin and Lods (in 1932), the house with shell structure in reinforced concrete and cladding panels of pumice-cement by Mebes (in 1932), the "Tri-ply" cast on-site system (1934), Farwell Bemis's systems "Cubical modular design" (in 1935), "Econcrete system" by Hayes based on standardised formwork (in 1938), and Nervi's patent for "structural prefabrication".

During the '40s, research and practice on prefabrication, not only with concrete, continued across Europe and the USA, leading to several different systems and sometimes radical outcomes: Neff invented the "Bubble house" created with inflatable formworks (in 1941), Wachsmann (F. 1-7, F. 1-8) proposed its prefabricated system for houses (in 1941), while the Pierce Foundation introduced its prefabricated systems in the USA (in 1941) and the Airey houses spread throughout England. In Italy, at the VIII Triennale (in 1945), the experimental neighbourhood QT8 was presented and, between 1947 and 1951, various Italian prefabricated systems were used for building experimental houses.

Between the '40s and the '50s the first well-known large panel prefabricated systems for residential building were patented and spread (e.g. Cauvet, Camus, Balencey, Coignet and Baretz); they are based on concrete large-format load-bearing wall panels, made with reinforced concrete cast on-site in standard formworks.

In both Great Britain and Germany, these early prefabricated systems based on concrete elements were not successful, largely due to the lack of planning and development resulting partially from inconsistent government support; in addition, technical problems such as cracking, leaking and corrosion frequently occurred, leading to the abandonment of the technology (Knaack *et al.*, 2012).

Meanwhile, in the USA, between 1945 and 1966 the "Case Study Houses programme" took place in California, involving notable architects. Inspired by the increasing interest of the American public in industrialised housing, the programme proposed 36 prototypes of 'mass production' houses, built with different new techniques: steel-framed structures, glass, and concrete. Although the use of precast concrete was only marginal, the programme clearly demonstrated a new attitude toward the use of standardised components.

As industrialisation drove the building industry in the USA, Germany, Great Britain, France and much of the industrialised world, many architects over the last century experimented with prefabricated systems for housing, and some of them are now considered pioneers of prefabrication. While the mainstream of research was prefabricating traditional homes, Richard Buckminster Fuller experimented with futuristic-looking buildings and new shapes and materials ("Dymaxion House" in 1928, "Dymaxion Deployment Unit" in 1940, "Wichita House" in 1945). Konrad Wachsmann, together with Walter Gropius, proposed a prototype of house built with a wooden panel system (the “Packaged House” in 1942, later housing programme for veterans - F. 1-9, F. 1-10). Jean Prouvè with its “Maison Tropicale” (in 1954) showed the first ‘true’ example of system building: prefabrication of components, which can be transported, assembled or disassembled to a complete form. Fritz Haller devised the three long span systems (“Maxi” in 1963, “Mini” in 1969, and “Midi” in 1980) intended to create wide spaces for industrial and commercial uses. Alison and Peter Smithson showed an honest approach to the new plastic materials using plastic-impregnated fibrous plaster to create curved forms (“House of the Future” in 1955-1956). Paul Rudolph applied the aesthetics of the new brutalism designing a spatial system based on trailer-like boxes laid on two levels in the “Oriental Masonic Gardens” (in 1968-1961).

On the other hand, during the twentieth century important developments were also carried out in concrete <u>prefabrication at component level</u>. Consequently, while reinforced concrete was being widely adopted for structural purposes, a huge structural and architectural repertoire of concrete facade elements was also developed, ranging from large panels down to small masonry units. With concrete elements produced in series in precasting plants (through prefabrication), especially regarding their use in the facade, a better quality, accuracy and standard of surface finish could be achieved.
Throughout history, the applications of cement-based and cement-bonded building materials, according to the aesthetic effects which could be obtained, included fair-face concrete, precast concrete, reconstructed stone panels, facing concrete masonry units and cement-bonded sheets (Herzog, 2008).
As already mentioned, at the beginning of the century John Earley had already pioneered systems that contributed much to architectural concrete in the USA, especially with the precast exposed aggregate concrete cladding with the MoSai technique[13]. In the first decades of the twentieth century, architects like Ernst May, Walter Gropius and Frank Lloyd Wright worked on concepts involving considerable prefabrication at system and component level.
In the following decades, especially during the ‘50s and ‘60s, construction with large-format load-bearing wall panels became widespread, leading to the realisation of very repetitive facades. However, many architects formulated architectural answers to the use of precast concrete in the facade, which were characterised by a formal yet differentiated use of precast elements, passing beyond previous attempts.
Such was the case of Marcel Breuer, who dedicated a significant part of his works to prefabrication, in particular developing the modular prefabricated concrete panel façades that first enclosed the IBM Laboratory in La Gaude, France (in 1961) and went on to be used in many of his institutional buildings (IBM Corporation Offices, Laboratories and Manufacturing Facility in Boca Raton, USA, in 1968-1974; Cleveland

[13] The evolution of precast concrete cladding in the USA, and especially the works of John Earley, is presented by Cellini (2008).

Trust Company, Headquarters, Cleveland, USA, in 1971). An interesting solution of a precast concrete facade component was also developed for the Torin Corporation Factory (Nevilles, Belgium, in 1963-64, F. 1-17, F. 1-18), defined after the construction of a series of facilities for the company across the USA[14]. While some critics reported the repetitiveness of his work, Breuer's ideas represented a significant progress in the design of architectural concrete and prefabricated components.

The experiences carried out before World War II, especially with concrete, were reapplied from the early '60s with public housing programmes across Europe. Large concrete panel systems were enormously widespread, accounting for 60% of all housing in the DDR in the '70s, 50% of all housing in Finland in the '80s, and a remarkable 75% of all housing in the Soviet Union by the '90s (Knaack *et al.*, 2012).
Slab building was, in fact, the response to the post-war housing shortage and dominated the residential landscape, especially in Eastern Europe, often disregarding ecological and design questions and leading to monotony and exacerbating the negative image of concrete.
In Great Britain too, an ambitious reconstruction programme was proposed after the war: the production of a large amount of new dwellings was to be realised through innovative methods of construction, which included prefabrication in concrete (Wall, 2013). The first response to the lack of housing focused on temporary buildings, based on lightweight steel or timber frame and cladding panels in various materials - from metals to cement-asbestos and reinforced concrete (Portal House, Arcon, Uni-Seco, Tarran, AIROH)[15]. After 1948, the housing programmes shifted to concrete building systems for high-rise buildings, which were similar to the slab system, such as the Wimpey No-Fines system[16]. In the '60 precast concrete systems building rapidly became the public face of industrialisation (Wall, 2013) and was used mainly for large housing projects (the large-panels concrete systems such as Bison), thanks to the modular coordination and the use of ready-mixed concrete. Despite their cheapness and quickness, the success of these building systems in Britain ended in the late '60s, with the general decline in industrialised housing.
An attempt was also made in post-war France to solve housing shortages through light-prefabrication, and even Jean Prouvé was commissioned in 1944 by the Ministry of Reconstruction and Urban Planning to design and build emergency shelters. However, concrete prefabricated systems (Camus, Balencey, Coignet etc.) gave the France of the ‘50s and ‘60s pre-eminence in European concrete prefabrication and

[14] Marcel Breuer complete work is included in recent publications (Breuer *et al.*, 2003; McCarter and Breuer, 2016), additionally the Marcel Breuer Digital Archive, curated by Syracuse University Libraries, is available online at www.breuer.syr.edu.

[15] Historic England, *PREFABS: Factory homes for post-War England,* available at viewfinder.historicengland.org.uk/story/intro.aspx?storyUid=44.

[16] Based on metal prefabricated frame-works and in-situ concrete with no fine aggregates, introduced from the Netherlands in the '20s.

determined the spread of the *grands ensembles* of social housing blocks in the outskirts of nearly every town in the country.
Even other western European countries, especially Denmark and Sweden, developed precast concrete panel systems - such as the Larsen-Nielsen Danish system (Caldenby and Wedebrunn, 2010).
A number of social housing complexes across Europe and the USA are meaningful examples of the lights and shadows of these concrete prefabricated systems: from the Pruitt Igoe in St. Louis, built in 1954 and demolished in 1972, or the Corviale in Rome, built in 1970 with its enormous scale and dramatic social conditions, for which new initiatives are now in place.

Besides international practice, in Italy, some main themes characterised the advancements in prefabricated construction and industrialisation during the post-war period: the INA Casa Plan which, aiming to create more jobs and favouring traditional building techniques, narrowed down enthusiasm about prefabrication; the experiments in the school building sector, favoured by the raising of compulsory school age; the short experiments in the public housing industry that were based on French industrialised systems; the parallel experiments in the industrial sector in which engineers exhibited their utmost skills (Iori, 2012).

The concept of modularity, which has in any case always been used as a design tool in architecture, emerged in early craft-prefabricated systems based on modular coordination, such as wooden construction (from the balloon-frame to the Japanese house). Since craft-prefabrication (as old as the history of building and originally meant for producing repeated pieces for realising a single work), the idea of the building has increasingly referred to a complex consisting of parts, subsystems or partial systems, connected by a large amount of parameters, and, concurrently, the focus has been more and more the possibility of managing the industrial production and the use of prefabricated building elements.
From the industrial revolution on, there was a gradual abandonment of traditional craftsmanship methods in favour of the increasing influence of the machine in the various production cycles, including the building industry; with the construction of the great cast-iron engineering works of the 19th century, the possibilities for prefabrication were seriously exploited for the first time and the module went back to being a fundamental tool of dimensional discipline.
Furthermore, research into rationalization, standardization and definition of types characteristic of the first decades of the twentieth century, driven by functionalism, implied a renewed attention to the issue of constructive and compositional modularity. Relevant research studies were carried out by prominent figures, which introduced ideas on modular coordination in building (Alexander Farwell Bemis in the '30s) or proposed new scales of proportion (the Modulor by Le Corbusier in 1943).
With the post-war experiments, prefabrication, understood as the complete production of finished parts, established the need for precision, quality and cost control: the module-object consists of two-dimensional or spatial units of complex structures made

by combining simple and constant elements (Wachsmann and Gropius, Beaudouin and Lods). Thus the concept of module assumes the validity of absolute law through technological standards, becoming the ‘measure of space’.
The need to find a module as the “dimensional reference which could connect all the building parts in a system coherent to the functional needs and which concurrently respects the continuity of surfaces and volumes” was already introduced in Italy in the ‘40s (Chessa and Zanuso, 1946).

In general, the importance of modularity in the design is essential to ensure the control of space, in relation to the needs (and therefore the functional and quality standards), through elements which have characteristics of unification and modularity (where possible), and also to ensure spatial and assebly flexibility, as the ability of the elements or parts of the system to be modified or replaced without affecting other parts of the building. With the serial production of components in particular, e standardised unit dimensions allowed parts to be mixed and interchanged at will, functioning along the same principles with which the assembly line worked for the production of automobiles. The theme of modularity thus became even more essential in the development of prefabricated systems, not only in terms of the dimensioning of the component but also in terms of dimensional coordination rules for interfaces and joints. Thus prefabrication highlighted the issues of modular coordination, understood as the modularisation in the building industry with a coordinated set of modular dimensions for the building elements, which then saw different developments in the national and international context.
While the theories on modularity of Wachsmann and Le Corbusier were already known and partially adopted in various countries, internationally coordinated research into a ‘universal module’ was begun in 1954 with the EPA (European Productivity Agency) Project 174 by the OEEC European agency. The project, focusing on the need to find common modular systems, tolerances and assembly instructions for the building industry, led to the definition of a base module of 10 cm (EPA, 1961). The ISO institution later agreed on a recommendation based on a measure of 10 cm for countries using the metrical system and 4" for the countries using the imperial system. In Great Britain, for instance, modular coordination was achieved in the '60s, with guidelines such as the “Building Research Station Module Chart” of 1960, issued by the British BRS (Building Research Establishment). Research into modular coordination was already started in 1947 by the British Standard Institutes, and an important step of that process was the foundation, in 1953, of the Modular Society (Wall, 2013).
In Italy, the issues of modular coordination were explored mainly with the activity of the National Research Council (CNR) which, from 1949, and especially under the leadership of Giuseppe Ciribini, focused on the specific themes of building industrialisation, standardisation and regulation.

Industrialisation and prefabrication in Italy and the experience of industrial buildings

While the beginning of industrial design coincided with the introduction of industrial manufacturing, this did not happen for architectural production (Trivellin, 1998); moreover, the relationships between design, architecture and industry show substantial differences according to geographical contexts.
In the USA and Europe the concept of serial production was introduced with industry, and standardised production processes started to be applied in both product and architectural design. In this sense, architectural work was seen as a unique composition of serial parts and components. In Italy, cultural awareness of the links between architecture, design and industrial production was realised only after World War II, as political and economical factors had longer hampered the development of a proper connection between industry and the building sector.

A number of figures, in Italy, dedicate their work and research on these topics, and their results and commitment in favour of building industrialization are notable.
On the one hand, figures such as Giuseppe Ciribini and the activity of the CNR, committed to issues of unification and modular coordination in construction since the '50s, actively contributed to the debate on building industrialisation and standardisation in Italy. About building industrialization, Ciribini introduced the simple valid definition of industrial method as the procedure of production, which rests solely on repetitive processes, set levels of executive consistency and limited and totally mechanized operations. Thus prefabrication, which he often preferred to define industrialisation, gives the opportunity to design and build freely combining parts of the building which are industrially produced and chosen from the many that the market can offer (Ciribini, 1958; Ciribini, 1967; Bosia, 2013).
Other figures explored the field, focusing on the implementation and experimentation of prefabrication and industrialisation in architecture. An important contribution was introduced by Marco Zanuso, whose practice was focused upon the concept of industrialisation as a means of production of objects, components and buildings. Zanuso's initial interest in prefabrication as a solution for reconstruction after the war (Chessa and Zanuso, 1946) was later skilfully exploited in the factories designed for Olivetti (F. 1-21, F. 1-22).
Furthermore, Pierluigi Spadolini, in his discussions on design and technology (Spadolini, 1967; Spadolini, 1974), also expanded upon the issue of combinability, especially with the programme for prefabricated post offices (in 1977), opting for an industrialisation of the components which could then be combined in different models of the same building (F. 1-23, F. 1-24).
Nevertheless, despite the initial commitment to these issues, even the most important Italian building programme during the post-war period, the INA Casa Plan (1949 - 1963) - according to its very nature - did no go beyond *semi-prefabrication* (Di Biagi, 2001; Capomolla and Vittorini, 2003) and a working committee on the issue of

modular coordination was in fact established for the Gescal Plan (1963-1973) only in 1965 (Trivellin, 1998).

After the war, the themes of industrialisation and prefabrication were, however, a flourishing field of application for the Italian construction industry, with the development of heavy prefabricated systems and components in precast and prestressed concrete.
The serial production of buildings for industry was, in particular, the first opportunity for the production of 'finalised components' (Mandolesi, 1978) - initially for the structural frame of the single-storey industrial buildings, then for the skeleton or the bearing panels for multi-storey buildings, and finally for the skeleton together with horizontal and vertical structures and internal partitions -, and was also seen as a chance to overcome the 'closed-system' prefabrication (Mandolesi, 1994).

The debate around building industrialisation and prefabrication in Italy was aroused during the reconstruction[17], with the contribution of prominent figures such as Mario Ridolfi and Ignazio Gardella, at the National Conference on Reconstruction in Milan (in 1945); during the '50s, the debate and concern on these topics was amplified by the activities of the Triennale (1947-1951-1954) and CNR (National Research Council - foundation of the Centre for studies on housing), and also through applied-experimental initiatives (as already mentioned, the construction of the QT8 housing estate). The '50s ended with the constitution of the Italian Association for Prefabrication (*Associazione Italiana Prefabbricazione*, 1957) and the Exhibition-conference on Prefabrication in Naples (1958), while the '60s began with the First International Exhibition-conference on Prefabrication in Milan (1962)[18]. Later, relevant research studies were carried out under the coordination of the C.T.E. (*Collegio dei Tecnici della Industrializzazione Edilizia* - College of the Specialists for Building Industrialization) and also expanded upon the themes of industrialization and prefabrication[19].

During those years was launched the specialised press on the topic, which included journal such as *La Prefabbricazione* (*Collegio dei Tecnici della Industrializzazione Edilizia* - College of the Specialists for Building Industrialization, 1965-1989), *Prefabbricare* (*Associazione italiana studio sviluppo materiali e sistemi di prefabbricazione* - Italian Association for the development of material and systems of prefabrication, 1958-1970) poi *Prefabbricare - edilizia in evoluzione* (*Associazione Italiana prefabbricazione per l'edilizia industrializzata* - Italian Association for

[17] Details on the prolific discussions on prefabrication in conferences, exhibition and technical publication from the period are summarised by Talanti (1980).

[18] In detail, the first international conference in Milan pointed out several of the main issues related to theory and implementation of prefabricated construction principles, as reported in the conference proceedings (Associazione Italiana Prefabbricazione, 1962)

[19] (CTE, 1976; CTE, 1978; CTE, 1980).

industrialised building, from 1971), followed in the sequent decade by journals such as *MODULO - edilizia industrializzata e tecnologie in progresso* (from 1975), *Il Giornale della prefabbricazione italiana (1982-1999).* At the same time, national journals began to focus more closely to the theme of prefabricated buildings, as in the case of *L'industia Italiana del Cemento* (*Associazione Italiana Tecnico Economica del Cemento* - Concrete Technical Italian Association, 1929-2009), which from 1964 dedicated a series of issues and articles to the topic[20], or *Domus* (1929-1955), which from 1972 introduced the editorial *PREFAB* about the various aspects of the topic[21]. Since the '60s prefabricated systems have been included in Italian architectural and engineering handbooks, while specific manuals about precast concrete systems were also edited and published (Koncz, 1962; Koncz, 1969).

Among the most significant practices on prefabrication during those years, beside industrial buildings, were the projects and programmes developed for the residential, public and school sectors. Following the experience of the CLASP system for prefabricated schools in Great Britain (in 1957), a school-building plan was proposed in 1959 in Italy, based on lightweight systems (the CLAPS, FEAL, VAR M3 systems, the Leonori and Lenci system, the Valdadige and Valle system)[22].
Additionally, the prefabricated systems developed in France gained special attention in Italy (Trivellin, 1998), especially as regards the large panel construction for residential buildings, the subject of many publications of the period (Del Bufalo, 1964). This is why in 1963 the IACP Lombardia (with the advice of Ciribini) imported the major French systems for heavy prefabrication (Camus, Coignet, Balency, Baretz, Fiorio), applied in social housing neighbourhoods such as the Quartiere Olmi a Baggio, Milano (Balency MBM)[23].

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[20] Two special issues in 1964 were dedicated to the theme of prefabrication and included the point of view of prominent figures such as Albini, Berio, Bianchi, Chiaromonte, Franco, Giangreco, Golineli, Imp. Grosseto, Lambertini, Levi (Albini *et al.*, 1964) and Manfredi, Mantelli, Marsili, Morandi, Nervi, Piccinini, Ponti, Provera, Rogero, Salvati, Valle, Ziino (Manfredi *et al.*, 1964); the theme however continued to be widely discussed until the ‘80s (Meregaglia, 1964; Zignoli and Castiglia, 1964; Giay, 1964; Del Bufalo, 1964; Del Lago and Cislaghi, 1977; Cislaghi and Del Lago, 1977; Tognon, 1980).

[21] The series PREFAB included many articles on specific topics (Corsini, 1972; Biondo and Rognoni, 1976g; Biondo and Rognoni, 1976a; Biondo and Rognoni, 1976b; Biondo and Rognoni, 1976c; Biondo and Rognoni, 1976d; Biondo and Rognoni, 1976e; Biondo and Rognoni, 1976f; Biondo and Rognoni, 1977; Joly, 1978).

[22] The theme of prefabricated construction for the school building sector in Italy is widely presented in Giannetti, Ilaria 2012, *Costruire la scuola. Progetto e produzione in Italia dal dopoguerra e gli anni ‘80*, Ph.D. Thesis, advisors Sergio Poretti and Tullia Iori, Università degli Studi di Roma Tor Vergata.

[23] The theme of prefabricated construction for residential building in Italy is significantly discussed within the research project of the University of Rome, Tor Vergata, coordinated by Sergio Poretti, *La costruzione industrializzata in Italia tra gli anni '60 e gli anni '80. Modi e tecniche di conservazione e recupero*, funded under PRIN 2008 (prin.miur.it). A significant overview of the introduction of prefabricated building system in Milan is presented in ALBANI, Francesca. 2014, *La prefabbricazione, strategie per la ricostruzione a Milano. Dalle sperimentazioni alle realizzazioni* (Albani and Di Biase, 2013).

The use of precast concrete façade elements was also adopted in notable public and residential projects (F. 1-19, F. 1-20) such as the Rinascente in Rome (Albini, 1961), the Engineering Faculty pavillion in Cagliari (Mandolesi, 1963)[24], the headquarters for La Nazione in Florence (Spadolini, 1966), and the Gallaratese tower-blocks in Milan (Magistretti, 1967).
Furthermore, during the '70s, also in Italy a number of prefabricated large-format load-bearing wall panels systems, based on the French model, were also devised in Italy (Zanussi Farsura, TEO Valdadige, Borini, MBM Meregaglia, Recchi) and 'tunnel formwork' systems were applied for the first time. In this period other important initiatives and studies were carried out on prefabrication, such as the construction of the already mentioned Corviale in Rome, an example of the Italian semi-prefabrication (in 1973), the prefabricated system for post offices by Spadolini (in 1974), and the programmes for prefabricated emergency constructions for the Friuli earthquake (from 1976) and later for the Irpinia earthquake (from 1980).

In general, it is evident that, in Italy, the industrialisation of the construction sector as regards residential building followed that of the other European countries, which took place mainly during the post-war reconstruction, by about two decades (Poretti, 2009). The reasons lie in several related factors. On the one hand, the prefab market was created and developed, in fact, only in the '60s, following the economic expansion cycle started after the war (Gregotti, 1986). Moreover, the advancement of the industrial sector, already underdeveloped if compared to other European countries, was greatly affected by the lack of a programme for building industrialization, with the absence of modular planning and precise legislation resulting in no coordination or homogeneity (Gregotti, 1986). However, this lack of homogeneity in production resulted in the introduction of alternative solutions for prefabricated systems. From the studies and experiments started after the war, an 'Italian prefabrication', based on prefabricated skeleton systems was thus developed and spread in particular throughout the non-residential sector (Iori, 2012; Iori and Marzo Magno, 2011). In that context, the aim of standardisation offered various groups of designers the opportunity to explore new architectural languages, especially in industrial architecture (Desideri *et al.*, 2013).
Among the solutions devised were several formal hypotheses designed with the specific intention of also solving the aesthetic issues of prefabricated construction, hitherto unexplored, especially in the field of precast concrete (Gregotti, 1986).

These considerations made evident the link between prefabrication and industrial building types within which the repertoire of the building techniques of industrialised construction has fully unfolded since the middle ‘50s. Advanced design, prefabrication and component production, in fact, finally realised as a technique of building

[24] The project and the construction of the Engineering Faculty pavilion has been presented recently by Sanna and Monni (2016).

industrialisation in the construction of industrial facilities and infrastructures, sectors in which the idea of planning and control of the production process was already established (Barazzetta, 2011).

It is no coincidence that the first issue of PREFAB, the series of articles devoted to prefabrication in Domus from 1970 to 1980, was dedicated to prefabricated factories as *Industrialised prefabrication in concrete* (Biondo and Rognoni, 1976g).

In those years, several authors discussed the role of architects in prefabrication, and how «il ruolo progettuale, sia a livello del disegni del componente che al livello della composizione dell'organismo, dovrà essere quello di dare con le proprie opere un significato alla prefabbricazione [...] cosicchè l'impegno, non diversamente da quanto avveniva per gli architetti del passato, rimarrà quello di testimoniare il proprio tempo[25]» (Corsini, 1972). Mangiarotti too had already highlighted that the time was ripe to conceive with absolute conviction of architectural production process in terms of industrialisation, at least to lend the works the necessary historical relevance.

In this sense, it is emphasized that «parlare di design nella strategia dei componenti edilizia non significa valutare il singolo componente come un'entità formalmente ed esteticamente autonoma [...] ma bensì vedere l'intero sistema della prefabbricazione industriale, basato sulla combinatorietà e la differenziazione modulare, nel suo rapporto con il disegno dell'intorno architettonico[26]» (Gregotti, 1986). Moreover, «one of the most interesting effects of prefabrication on architectural research could be seen in the approach taken by the design sector towards building construction. The designer was not involved in the prevailing ideological approach to industrialisation, which gave him the opportunity to focus on restyling the construction unit. [...] That brought about typically Italian results and widened the 'made in Italy' production range, making it more popular worldwide» (Iori, 2012).

In this sense, the significant episodes of post-war industrial architecture and their links with the development of building systems and prefabrication should be considered (F. 1-25 - F. 1-40).

The construction of <u>large-scale engineering works become a first opportunity for original solutions of 'proto-prefabrication' of concrete</u> (Iori, 2012). Pier Luigi Nervi introduced the *structural prefabrication* - patented in 1939 -: the idea was to break down the large reinforced concrete structure into small pieces to be prepared on site, and was used for the first time in the second series of hangars in Orvieto (Giay, 1964). The idea was not to design industrial components but to define a system - or better, a series of operations carried out on site - to prefabricate special elements which

[25] The project, at the levels of component design and building planning, would aim to give meaning to prefabrication through the architectural work [...] so that, as it was for the architects of the past, their main commitment would remain to witness their time.

[26] Talking about design referring to the building components does not mean considering the individual component as an entity formally and aesthetically autonomous [...] but rather seeing the whole system of industrial prefabrication, based on combinability and modular differentiation, in its relationship with the architectural design.

compose the completed work. Thus the purpose was a whole system of separate pieces which were formed on the building site and then assembled, reducing the time and costs related to large and complex formwork. The use of *ferrocement* - patented in 1943 - allowed Nervi to produce small lightweight pieces in thin-shell concrete, accurately moulded into particular shapes by a special process of generation. Finally, for the Palazzetto dello Sport and the Palazzo dello Sport (EUR) in Rome Nervi proposed a refined system of on-site prefabrication, based on a series of multiple casting moulds - known as the *grandmothers, mothers and daughters*, and patented in 1950 - (Olmo and Chiorino, 2010; Iori and Poretti, 2010).

Between the ‘50s and the ‘70s, many other Italian designers also experimented with the use of prefabricated concrete elements in industrial construction: several of them took the opportunity to introduce new technologies and brand-images by designing their own precast concrete elements, while others exploited the possibilities presented by prefabrication and standardisation to inject their personal modernist language into industrial architecture.
The second category included those architects who stood out for their ability to combine the products provided by the industry to build unique architectural works. In this sense, the experiences of Vittorio Gregotti, Pierluigi Spadolini and Gino Valle, although very different, reveal a similar attitude to prefabricated construction and an approach oriented to the building as a whole rather than to the single component (Barreca, 2015).
On the contrary, for other designer the factory was an opportunity to reshape the trilith using current concrete technology and redesigning the construction units (Iori and Marzo Magno, 2011). In this sense, industrial buildings, consisting of elementary components for vertical structure, horizontal structure and roof, as a result of an assembly processes reduced to essentials, were also an opportunity to propose exemplary architectural solutions for the beam-column structural node (Barazzetta, 2011). In the practice of Marco Zanuso, Vico Magistretti and Angelo Mangiarotti, the prefabricated elements were thus conceived - also through innovative forms and solutions - to fulfil the overall design concept. As just remembered, Marco Zanuso realised his ideas of industrialisation and prefabrication most fully in the industrial plants designed for Olivetti[27] in other countries (Merlo, Argentina and San Paolo, Brasil) and in Italy (complexes in Scarmagno, Crema and Marcianise, with Eduardo Vittoria). Mangiarotti, coherently with his discourse on prefabrication and industrialisation in architecture, in the '70s was committed to the design of prefabricated structures for industrial building, devising the Facep, U 70 Isocell and Briona systems.

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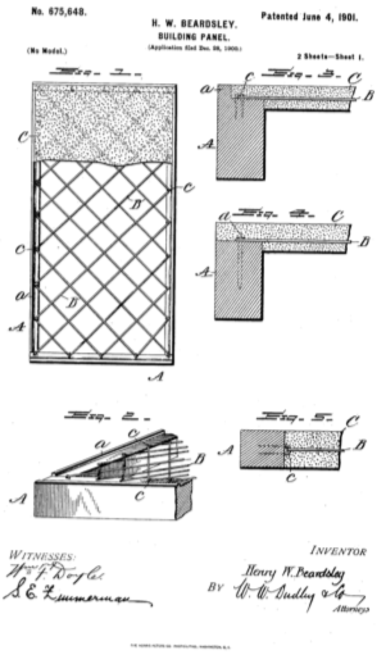
[27] The relevance of the collaboration between Marco Zanuso and Adriano Olivetti for the construction of industrial buildings is, for instance, highlighted in a recent study by Francesca Cigliano (2010) *Marco Zanuso ed Adriano Olivetti: Industrializzazione e progetto.* Master Degree Thesis, Politecnico di Milano, advisors Giulio Barazzetta and Marco Biraghi.

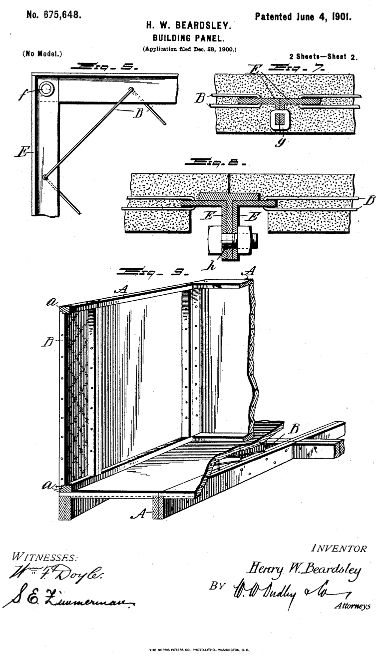
For many other designers, architects and companies, the industry of prefabricated systems became also an opportunity to design and propose unique precast concrete elements - especially façade panels - as serial products to be used for industrial building, according to standardised systems.

As a consequence, these attitudes towards prefabricated systems led to the construction of many factories across the country, constituting some of the most successful examples of industrial building of the late twentieth century.
However, since the diffusion of the early prefabricated systems for industry, questions about the values of this architecture have constantly arisen. In the past, architects discussed whether a repetitive built environment can be planned intelligently and provide the essence of architecture, or wonder if, in the search for individuality and corporate identity, mass customisation suffices in architecture (Knaack *et al.*, 2012).
Nowadays, these issues have become even more relevant due to the increasing need of initiatives for the preservation, valorisation, refurbishment and reuse of prefabricated built heritage (Graf and Delemontey, 2012).

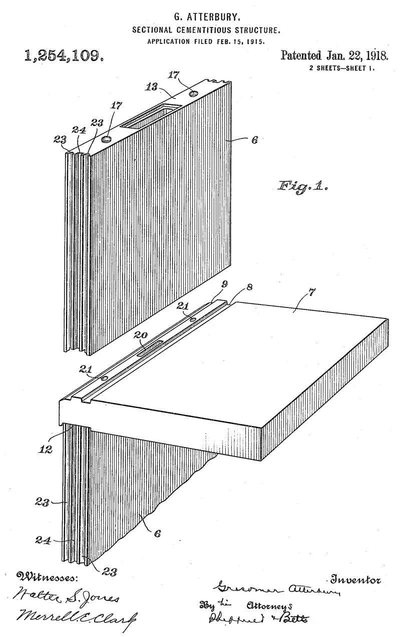
This is the case of industrial building in Italy where, since the last century, the prevalence of prefabricated industrial architecture has become increasingly evident, also in relation to the industrial recession and the phenomenon of abandonment. This vast diffusion of precast concrete structures is characterised by a specific typology of building envelopes, made with precast concrete panels, which also define the industrial landscape of the country.
Thus, this study addresses, in the following paragraphs, the evolution of this building process, the industrial production related to it, and the work of the designers of that period, focussing on these façade elements, aiming to provide a useful background for discussion of the issues of preservation and transformation.
In this sense, the wide variety of types of early precast concrete panels, and of the typologies deriving from the implementation of different assembly systems, constitutes an initial element for these studies' evaluation and critical understanding of Italian industrial heritage, despite the triviality, repetitiveness, and redundancy of post-war precast industrial buildings, which nowadays usually results in their being appraised negatively.



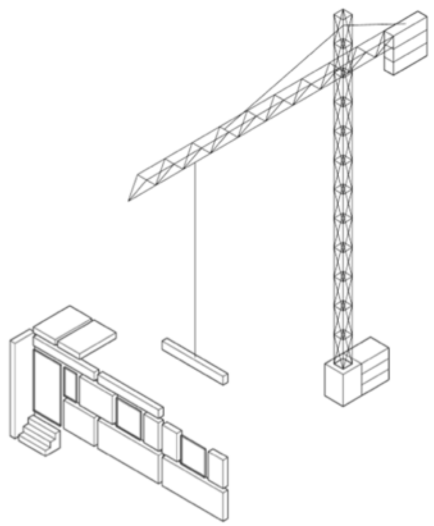
F. 1-1: “Building-panel” by Henry W Beardsley (1900-1901) patent US 675648 A (Google patents)



F. 1-2: “Building-panel” by Henry W Beardsley (1900-1901) patent US 675648 A (Google patents)



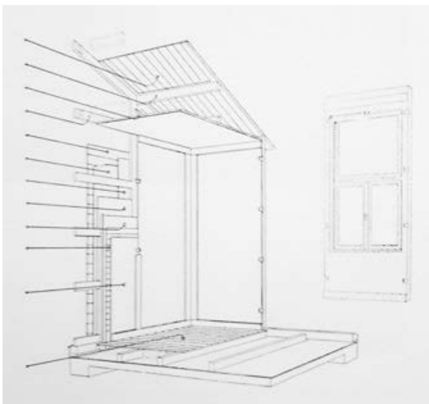
F. 1-3: “Constructional sections” - concrete hollow panels - by Grosvenor Atterbury, (1915-1918).patent US US1254109 A (Google patents)



F. 1-4: assembly system of the "Frankfurter Plattenbau" by Ernst May 1926-1930 (Knaack, 2012)

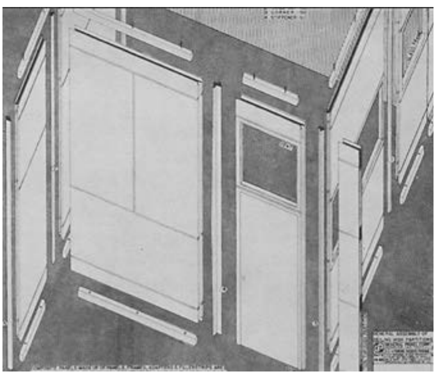
F. 1-5: “Airey house” in UK (Concrete Quarterly, 2, 1950)

F. 1-6: typical ‘plattenbau’ construction in Germany, Stasi Museum, Berlin, 1950 (www.stasimuseum.de)



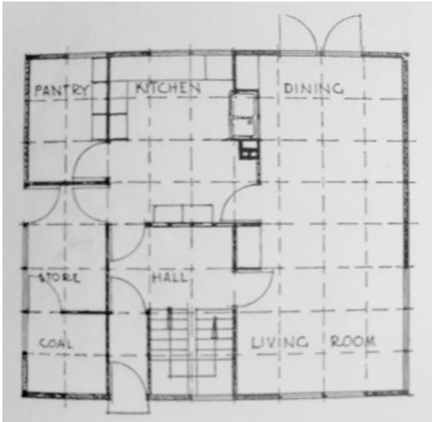
F. 1-7: Panel System, K. Wachsmann, late '20s (Wachsmann, 1995)

F. 1-8: House at a Tennis court in Berlin, K. Wachsmann (Wachsmann, 1995)



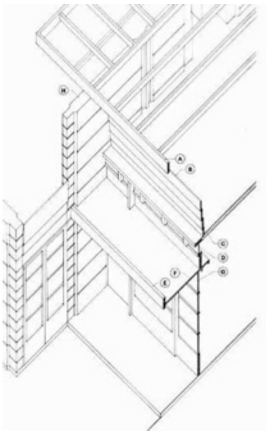
F. 1-9: “Packaged House” system, 1942-1952, Wachsmann & Gropius (Casabella, 244, 1960)

F. 1-10: "Packaged House" Sysem, 1942-1952, Wachsmann&Gropius (www.harvardartmuseums.org)



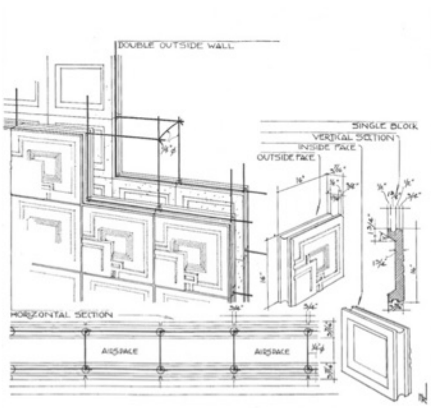
F. 1-11: house 17, Weissenhof Stuttgard, 1927(Blundell Jones, 2002)

F. 1-12: house 17, Weissenhof Stuttgard, 1927 (Blundell Jones, 2002)



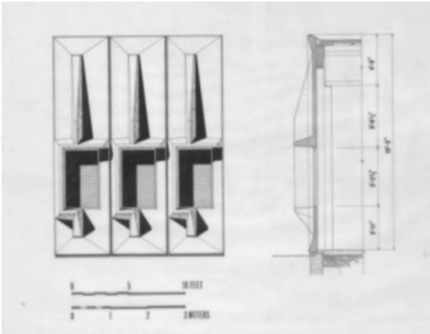
F. 1-13: El Pueblo Ribera Court, La Jolla, USA, 1923, Rudolf M. Schindler (Ford, 2003)

F. 1-14: El Pueblo Ribera Court, La Jolla, USA, 1923, Rudolf M. Schindler - (archlabmathijsdewit.blogspot.com)

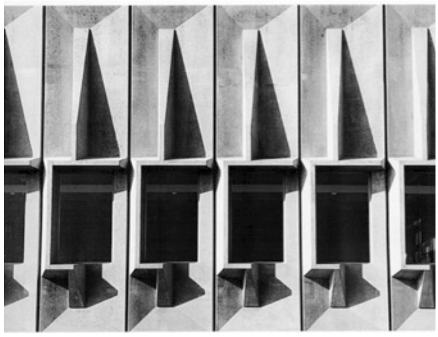


F. 1-15: drawing of the pieces for the Usonian Automatic, 1926, F.L.Wright (Trivellin, 1998)

F. 1-16: textile blocks in the Millard House (La Miniatura, 1923, F.L. Wright (www.archdaily.com)



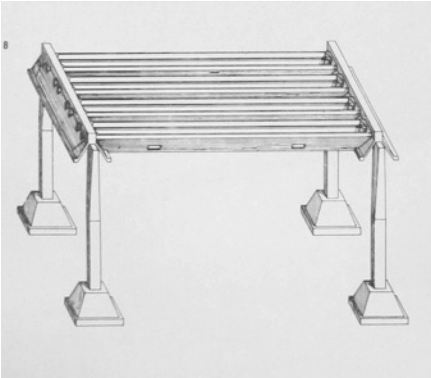
F. 1-17: studies for the façade panels of the Torin Corporation, Nivelles, BE, 1963.1964, Marcel Breuer and Hamilton Smith (breuer.syr.edu)



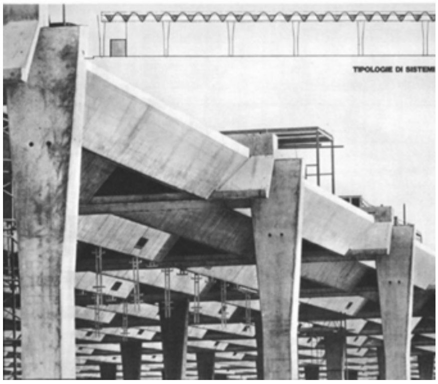
F. 1-18: façade in precast concrete panel of the Torin Corporation, Nivelles, BE, 1963.1964, Marcel Breuer and Hamilton Smith (Breuer, 2003)

F. 1-19: detail of the La Rinascente building at the XII Triennale, 1960 (archives.rinascente.it)

F. 1-20: La Rinascente building, Rome, 1961, Franco Albini (Domus, 1962)



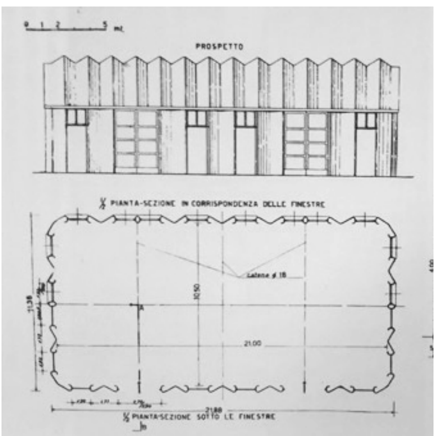
F. 1-21: construction scheme, Olivetti plants in Marcianise, Crema, Scaramagno, 1969, M. Zanuso (IIC, 1972)



F. 1-22: Olivetti plant in Scaramagno, 1969, M. Zanuso (Domus, 1972)

F. 1-23: post-office prefabricated system, 1974-1979, P. Spadolini (Trivellin, 1988)

F. 1-24: post-office, 1974-1979, Udine , P. Spasolini (author, 2016)



F. 1-25: ferro-cement warehouse, P.L. Nervi (Nervi, 2014)

F. 1-26: ferro-cement warehouse, P.L. Nervi (Nervi, 2014)

F. 1-27: Centrale del Latte, Torino, I, 1950-1952, L. Buffa (centralelatte.torino.it)

F. 1-28: Pirelli factory, Pozzuoli, I, 1954, L. Cosenza (atlante.iuav.it)

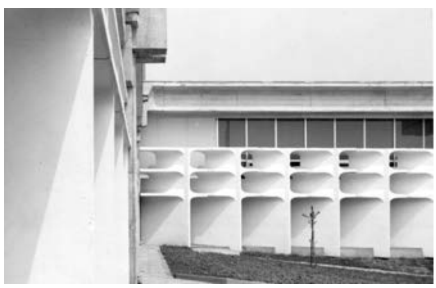
F. 1-29: Raffo factory, Pietrasanta, I, 1956, Calini Montuori Musmeci (atlante.iuav.it)

F. 1-30: Perugina factory, Perugia, I, 1961-1963, Rusconi Clerici (Rusconi Clerici, 1972)

F. 1-31: Morassutti warehouse, Mestre, I, 1959, Morassutti, Mangiarotti, Favini (Barazzetta and Dulio, 2009)

F. 1-32: Ceramica Pozzi factory, 1960-1964, Figini and Pollini (atlante.iuav.it)

F. 1-33: Gondrand centre, Milano, I, 1968, A. Favini (www.fondazionefavini.it)



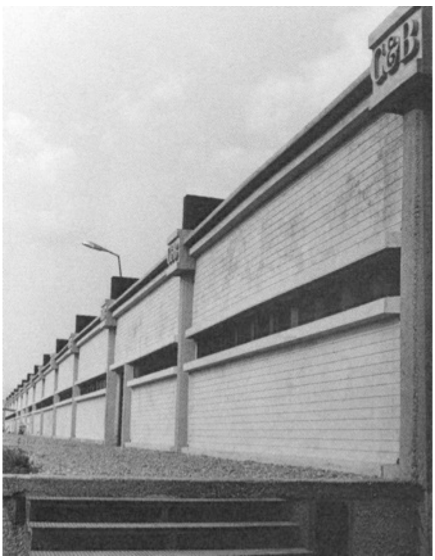
F. 1-34: Kodak factory, Caserta, I, 1974, G. Ghò and A. Favini (Ghò and Favini, 1976)

F. 1-35: ELMAG factory, Monza, I, 1966, A. Mangiarotti (Burkhardt, 2010)

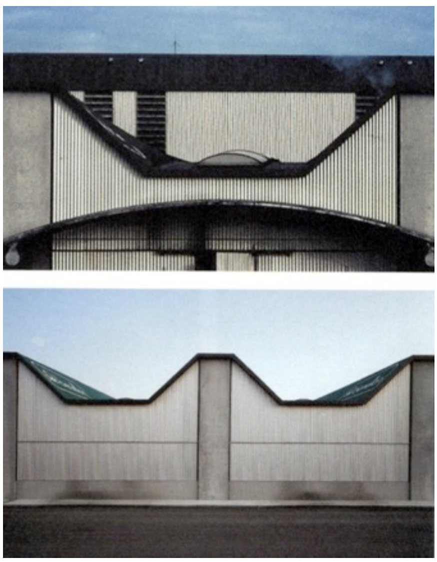
F. 1-36: Fiat dealership, Bussolengo, I, 1976, A. Mangiarotti (Burkhardt, 2010)

F. 1-37: FEG factory, Giussano, I, 1978, A. Mangiarotti (Burkhardt, 2010)

F. 1-38: UNIFOR factory, Turate, I, 1983, A. Mangiarotti (Burkhardt, 2010)



F. 1-39: B&B factory, Novedrate, I, 1966-1968, T. Scarpa (architetturadelmoderno.it)



F. 1-40: Benetton factory, Villorba, 1980-1985, T. Scarpa (Masiero, 2012)

1.1.2 Concrete prefabrication for industrial buildings: typological, constructional and technological aspects

Industrial architecture constantly evolved according to technological progress, in order to accommodate new manufacturing processes and benefit from new materials and construction methods. Thus the industrial building type developed over the last century from the large-scale engineering structures to widespread prefabricated constructions.

The prefabricated type, in the form of the single-storey pavilion with high internal seriality, was fully and generally adopted in Italy from the '60s, when it was established as a model of flexibility, integration and adaptability. This building type spread thanks to the possibilities offered by concrete technology and especially the introduction of precast concrete systems and components.

As precast concrete structures were introduced, the issue of cladding elements arose and led to the definition of specific solutions for precast concrete wall panels. The panels, initially devised as simple load-bearing components, gradually diversified according to their scope, pursuing even greater performance and also following a constant study of the architectural and aesthetic features of the industrial building.

Industrial architecture and the evolution of types and techniques

Although many authors have dedicated their study and research to the theme of industrial architecture at an international and national level (Raja, 1983; Banham, 1989; Castronovo and Greco, 1993; Darley, 2007; Parisi, 2011; Ciuffetti and Parisi, 2012; Vettori, 2013; Bertagna *et al.*, 2012), interest in the architecture of the factory appears to be quite recent in architectural history and in the past were directed predominantly to industrial archaeology - 18th and early twentieth century.

The first titles dedicated to contemporary industrial architecture in Italy were presented only in the ‘60s (Aloi, 1966; Forti, 1964; Guarneri and Morasso, 1958). Aloi included in his work more than 80 industrial buildings from the '60s, depicting the trend in industrial architecture in the country, the major developments in building types and techniques, and remarkable architects and engineers active in the field; among the buildings presented, several show a significant use of prefabricated systems and precast concrete elements. Shortly afterwards, Cavallotti too offered up a review of the most remarkable industrial building from that decade, but claiming that industrial architecture from the '60s, especially in Italy, favoured a discussion focused on the functionality of the factory and its spaces rather than its architectural features (Cavallotti, 1969).

Only later other studies have presented reviews of notable industrial sites in Italy, highlighting also the role of architects in the evolution of the modern factory (Castronovo and Greco, 1993).

In general, the development of industrial architecture was made possible by technological progress and, in fact, the factory constantly was reshaped to fulfil the evolving needs of manufacturing processes and benefited from the introduction of new materials and construction methods.
In this sense, studies of the history of industrial architecture define five periods of development of the architectural language of the factory: pre-industrial, palaeo-industrial, proto-rationalism, rationalism and post-war (Raja, 1983). The pre-industrial period (1750-1800) includes building still related to the rural tradition and mainly converted from other uses (i.e. the earlier wool-spinning mills) while later, in the palaeo-industrial period (19th century), a specific architectural language of industry was defined, with Eclectism as the dominant style and the widespread use of cast-iron. The proto-rationalist period (early twentieth century) corresponds to the maturity of industry, and was characterised by functionalism, with traces of Art Nouveau style and Expressionism. In this period the use of reinforced concrete started - with works such as the mills of Hennebique and the factories of Perret[28] (F. 1-43, F. 1-44). The Hennebique system in particular spread even throughout Italy and was then used for a number of industrial structures - silos, warehouses, mills (F. 1-41, F. 1-42)[29].
The rationalist period (1910-WWII) was characterised by the beginning of the 'modern industry' and an architectural language more focused on technological and practical issues. Remarkable buildings were realised: the factory in Purmerend by J.J.P. Oud (1916-1920), the Van Nelle factory by Brinkman ad van der Vlught (1927-1930) and the Lingotto factory by Mattè-Trucco (1916-1923). In Europe the rationalist language prevailed and concrete frames proliferated, while in the USA industrial architecture became an advertising means for the company, with masterpieces such as the Johnson Wax factory by Frank Lloyd Wright (1939) and the River Rouge complex (1917-1928) and the Chrysler plant by Albert Kahn (1936).
The post-war period showed a reduction in scale of the industrial buildings, with focus on the promotion of the company and easy accessibility. Additionally, industrial architecture started to be associated with standardisation and industrialisation of buildings. Prefabricated systems and components especially led to the contemporary image of the industrial building as a 'container', made of the cladding and its frame, reinforcing the idea of the building skin and its advertising function.

[28] The Esders clothing factory (1919) was followed by other remarkable examples of concrete industrial architecture by Perret such as the the Admiralty research laboratories in Paris (1928) and the Engineering Factory in Issoire (1939-1948) (Cohen *et al.*, 2002).

[29] Interesting examples of industrial buildings, warehouses and silos constructed with the Hennebique's system in Italy are presented by Nelva and Signorelli (1990).

Throughout this historical evolution, it is clear how important a role building systems and available materials and techniques played in the development of the industrial building types. The industrial building type was, in fact, rapidly introduced in response to entirely new problems and his typological and formal freedom encouraged designers and producers, from the 18th to the 19th century, to acquire, independently from official architecture, materials and techniques made available by industrial advancements thus inventing a new expressive language (Dassori, 2001).

Additionally, industrial architecture generated a number of technical problems that often promoted large-scale experimentation of building practices, so that design also became a means for highlighting the formal potential of new materials and construction systems (Nardi, 1986). All the main technical innovations could be identified, in fact, in the construction of industrial buildings, demonstrating innovation both in technical experiments and in construction and structural solutions (Barazzetta, 2011). This is why, as per the focus of this study, industry itself, which was both a producer and a user of new materials, was often the first client for the adoption of industrialised methods.

According to this interpretation, the evolution of industrial architecture becomes particularly relevant in the twentieth century when several key approaches in the design of industrial buildings as 'industrial products', and also exemplary moments of modern architecture, were established. This is why the commitment to the integration of design as serial production was so clear in the industrial building works by the Deutscher Werkbund, Peter Behrens and Walter Gropius, or the search for a new language for the *machine age* were so skilfully applied in the industrial building designed by leading figures of the Expressionism (Bruno Taut, Max Taut, Hugo Haring, Hans Poelzig), Futurism and Constructivism.

On the other hand, after the exemplary realisation of the Lingotto factory, industrial architecture in Italy followed the delay of modern architecture and only later resulted in the well-known examples of 'company architecture'[30]. Concurrently, the industrial and cultural development was initially not corresponded by research into the design of the factory, which was often considered purely in functional terms, neglecting the national architectural debate (Morganti and Tosone, 2013).

Only in the mid-twentieth century, it became clear that industrial architecture was characterised by a new idea of the factory made up of a variable balance between productivity, functionality of space and company image[31]. Moreover, industrial buildings were increasingly representative of the new material culture based on industrialisation and the use of serial production and prefabrication. Many examples of

[30] The idea of the 'modern factory' in Italy was implemented in the works of prominent figures such as Giuseppe Terragni (project for the Officine del gas in Como in 1927) and especially with the construction of notable companies' architecture (Olivetti ICO 1938 - 1942 and further extensions in 1956, and Olivetti factory in Pozzuoli by Luigi Cosenza in 1955) (Cavallotti, 1969).

[31] Considerations might also expand upon the evolution of the modern factory types as related to the functionality and liveability of spaces, demonstrated by many notable industrial building throughout Europe (Averna, 2005).

this approach could be found across Europe, from the research into utopian visions and industrialised systems by Buckminster Fuller, Konrad Wachsmann and Jean Prouvé to the innovation of industrial buildings constructed between the '60s and '80s by Richard Rogers, Farrell/Grimshaw, Foster Associates, Renzo Piano, Arup, DEGW, and James Stirling.
In Italy this approach was highlighted by the advent of large concrete works from the '50s and '60s (Cosenza, Figini and Pollini, Vittoria, Dolza, Morandi and Nervi) and experimentation with prefabricated systems (Zanuso, Mangiarotti, Magistretti), as already stated (F. 1-45, F. 1-46).

In general, functionality was one of the principal aspects which determined the evolution and spread of industrial building types from the ‘50s: as the use of the building and its contents were changing rapidly along with the organisation of the production cycle, for the first time the issue of ‘flexibility’ in architecture arose. Size, scale, integration and adaptability of the space became the main requirements of the industrial building and led, at the end of this development, to the diffusion and the success of the typical single-storey pavilion with high internal seriality and wide structural grid (Anastasi, 1983; Nardi, 1986; Parisi, 2011). The need for flexibility, free plan organisation, natural lighting and service integration oriented research towards specific building elements: such is the case of the evolution of roofs which, pursuing a ever greater span of the structures, later led sometimes to the abandonment of the former models (sheds and vaults) in favour of continuous roofing.
However, types of industrial building could still be very varied, being linked to the production activities and machineries that the building contained. This is why some complexes were characterised mainly by a variety of functionally different parts (silos, towers, ovens and chimneys) which, due to the oddity of their forms, constituted a heterogeneous environment (steel plants, chemical plants). On the other hand, all the other factory types evolved with no particular shape constraints, as large containers where processes and systems are placed in simple volumes. In parallel, the continuous change of production cycles implied a high internal flexibility and a wide range of uses for these modern factories, in which the simplicity of volumes represent a renewed form-function matching (Corsini, 1972). This second building type, characteristic especially of the small and medium-sized enterprises, is the one that witnessed the greatest use of prefabricated building systems. This trend, in Italy, led to a natural evolution of construction techniques for industrial buildings towards concrete prefabrication[32], which in the same period had been the subject of interesting developments and applications.

[32] On the other hand, in the Italian case, the use of metal structures for factory building was only marginally investigated in those years. The construction industry often proved to be quite indifferent to the achievement of quality excellence in industrial buildings and instead remained linked to convectional and ordinary solutions, while metal structures were little used due to the high production costs and the need for specialised labour (Morganti and Tosone, 2013).

As with the works of the Modern Movement, the factory had already been able to regain the dignity of architecture, and some results obtained with prefabrication in industrial buildings proved again the modernity, quality and potential of industrial architecture. Technological innovation - not common in residential construction - along with the respect of technical-economic needs can, in fact, be found in prefabricated industrial buildings as the effort to simplify the volumes, unify the components and enable expansions (Corsini, 1972).
In this sense, between the '60s and the '70s, the advent of industrialized construction techniques enormously changed the structural conception and the characteristic of the market for industrial buildings, and the image of the factory itself also underwent a major change (Biondo and Rognoni, 1976g). Furthermore, prefabrication considerably influenced the role of architects and engineers involved in the field, implying specialization and contamination of their respective areas of work; Banham noted how «however, there is a division of mind here between architects and engineers that goes much deeper. The operational lore of the architectural profession has assimilated prefabrication as a technique applied to fairly small repetitive components to be assembled on site. Such an arrangement leaves the determination of functional volumes still securely in the hands of architects, and the physical creation o those volumes securely in the hand of traditional-type site labour» (Banham *et al.*, 1997).
As a matter of fact, in Italy architects and engineers in the '60s, each with their own contribution, came up with new solutions for what is basically the classical trilith system: prestressed beams, pillars, wall panels and roof slabs (Biondo and Rognoni, 1976g). Since then, design and production activity have involved a wide typological range, for both slabs and panels (shape and surfaces). The technological standard increased remarkably between the '60 and the '70s: the resistance of the concrete elements was much improved, passing from slack reinforcement to prestressed reinforcement, the equipment and machinery were updated, the organisation on building sites was rationalised and the production times were speeded up. In addition, concrete technology itself evolved with the introduction of additives (fluidifiers, accelerators and retarders).
In the mid '70s there was a feeling that "the prefabricated model has been fully and generally adopted" and “a technological limit has been reached” (Biondo and Rognoni, 1976g). As a consequence, it was forecast that, unless some improbable revolution took place, the conception and the characteristic of factory-made prefabricated industrial buildings would remain very much the same as they were**.**

However, from the architectural and aesthetic point of view, at that point in the history/development of the industrial building type, criticism had already arisen about the pertinence of considering prefabricated structures 'true architecture'. These buildings often «offer a neutral image which is indifferent to matters concerning built surroundings, in which the modularity and the serial repetition of the components are easily identified» (Biondo and Rognoni, 1976g).
Despite many attempts to instil architectural quality in prefabricated buildings, several authors envisaged that the ‘marriage of design and series-manufacture’ did not exist

in the case of prefabrication for industrial building. This is why, up until the '80s, although architects continued their research and produced notable example of prefabricated architecture, the market was already pushing towards lower costs of components and the inevitable decline had started.

As a result, between the '70s and the '90s, a large amount of building was constructed with little consideration of architectural and environmental quality, composing the built environment which nowadays characterises the 'industrial landscape' of many sub-urban areas.

In 1980 the journal *L'Industria italiana del cemento,* for its 50th anniversary, presented an issue devoted to the "The progress of concrete in Italy". The section on concrete for industrialised building and prefabrication focused (again) on industrial buildings (Goffi, 1980; Tognon, 1980), as the sector which had undeniably had the greatest success in precasting techniques. However, as it was pointed out, such industrial constructions were increasingly frequently realised without external assistance by designers, as the prefabricated systems were often intended as a complete set of components which constitutes a ‘turnkey project’. On the contrary, it is - and was - evident that the role of designers could have been crucial, as in the previous decades, to coordinating the industrial products with the site-specific and architectural features of the project. In this sense, the evolution in techniques, promoted by construction companies, should also have concentrated on component production rather than standardised model-building.

The rapid spread of such mass-produced and low-quality industrial buildings has somewhat tarnished the image of prefabricated architecture which flourished during the '60s. As a consequence, nowadays, notable pieces of prefabricated industrial architecture cannot be found so easily: on the one hand, the rapid growth of industrial areas in the outskirts of cities had compromised many valuable industrial settlements, and on the other, a number of buildings have undergone major changes and modifications, thus losing their original architectural appeal.

Prefabricated concrete elements for industrial buildings

The construction types of prefabricated industrial buildings - besides being built as system building or using standardised components - can be divided, even today, into the categories ultra-lightweight, modular, steel skeleton, mixed concrete and steel skeleton and concrete skeleton buildings. The last category, with attention paid to its origins and its evolution over the past decades, is therefore the main focus of this study.

In general, prefabricated industrial building were often created for particular production processes and were designed to meet specific needs, so that the design consisted of a number of repeating components and the building could be viewed as a *customised system building with a high proportion of prefabrication* (Knaack *et al.*, 2012). Concrete skeleton constructions for single-storey industrial building represent this category well and have been developed, over the years, according to evolution in concrete technology. This is why, for instance, the use of prestressed concrete enormously expanded the structural possibilities of the system, changing also the building design.
After the introduction of the first prefabricated concrete elements at the beginning of the last century (beams, floor slabs, wall panels), and thanks to the diffusion of concrete skeleton systems (in the '50s), in Italy, from the '60s, the expanding industrial sector became the largest market of prefabrication (Giay, 1964). Furthermore, prefabricated concrete structures started to be preferred, in part due to their superior behaviour in fire, sound insulation and better options for surface finishing if compared to steel constructions.
As a result, in the mid-'70s, a considerable number of prefabricated buildings consisted of warehouses and factories - 29.5% of the total number of buildings, 45% of the overall built volume (Del Lago and Cislaghi, 1977). In addition, in the '90s, about 85% of the industrial building stock was made with prefabricated reinforced concrete structures (Faresin, 2009). This numbers also appear relevant in relation to the current amount of industrial building in the country, about 700,000 warehouses for a volume of about 7 billion cubic meters (FAI and WWF, 2012).

The main reason for the development of prefabricated elements for industrial buildings was the concept of *prefabricated system*, understood as a set of prefabricated components that define a constructive typology. This is why as the amount of industrial building made with prefabricated r.c. structures increased and the use of precast concrete wall panels spread until there was almost exclusive use of them in substitution of masonry walls (bricks, concrete blocks etc.), due to the same reasons: lower cost of labour, assembly speed, better performance and availability of system solutions.
Concurrently to the spread of prefabricated skeleton systems, the industrial building type was simplified and started to be classified by the number of storeys, the number

of aisles, or the type of roof (Koncz, 1969). More specifically, in the evolution characterising the industrial building type from the mid-twentieth century on, there is an evident link with the new construction techniques and especially with the possibilities offered by the introduction of precast concrete systems and components.

Nevertheless, the vicissitudes of precast concrete, in Italy, intertwine much earlier than is made evident by the many industrialized building systems developed after World War II. In fact, after the pioneering stage between the 19th and the 20th century, a rigorous phase of systematization of concrete technology began across Europe. In Italy too, the perception of the technical and economic advantages of prefabrication on-site of structural elements led to the production, during the first decade of the century, of many types of components for beams and lost tile concrete slabs[33]. Concurrently, decorative elements such as plates, pipes, and hollow blocks were already common due to the diffusion of the *Art Nouveau* style that promoted their earlier industrialisation.
After World War I, the need to limit construction costs favoured the introduction of more other prefabricated components intended primarily for making lost tile concrete slab floors or curtain walls (Dassori, 2006). Also the first precast concrete panels and concrete hollow blocks were proposed (F. 1-47, F. 1-48). Moreover, the earliest r.c. prefabricated systems for complete buildings were used for small railway service facilities (Lavizzari, 2006b).
In the '30s and during the Fascist regime, many floor slabs were patented (SAP, Stimip, SIF, LARES, Verrocchio), alongside with the well-known Varese beam system (1931), while the industry started producing other off-site prefabricated elements (mostly tubes and poles). It is agreed that industrial prefabrication of concrete elements in Italy started precisely from the production of tubes for drainage systems and centrifuged poles for foundation, in the '20s, and the first concrete floor slabs, in the '30s (Dassori, 2001; Lavizzari, 2006b). However, at the time, many other smaller precast concrete elements were widely produced: conduits, sewer covers, kerbs, pavements and banks, vineyard poles, tanks and windows (Rabbi, 1939).

Besides this former practice with precast concrete elements, the most relevant Italian experiences in prefabrication are considered those developed during the '50s and the '60s, with the mass production of structural elements - pillars, beams, and slabs.
In a first phase, after the post-war reconstruction, the industrial development led to an urgent need for new factories, which were traditionally made with vaulted roofs, truss

[33] The evolution of prefabricated elements in reinforced concrete is thoroughly explained by Enrico Dassori (2006): precast concrete components for floors and roofs included concrete trusses (Visentini system), hollow core beams with octagonal cross-section (Corradini system), hollow core beams with octagonal cross-section (Siegwart system), double-T beams (Dorella system), tubular elements for flooring with flat intrados and ribbed extados (Krattinger system), tubular slabs (sistema Herbst), double-T beams adjacent (Turk system), double-T beams spaced by small slabs (Gisshammer system), V-shape beams (Cicogna system), L-shaped consecutive beams (Ortogon system).

or shed (Lavizzari, 2006a). The vaulted type was once made of r.c. beams and pillars, cast on site, usually with masonry walls and lost tile concrete slab roofs, completed by metal tie-beams; the trusses of shed types were made with metal beams or, in some cases, with reinforced concrete elements cast on site.

Prefabrication was adopted for the first time in the construction of industrial buildings with the precast reinforced concrete arches for the vaulted roofs (F. 1-53, F. 1-54) which characterize the building stock of the '50s. The prefabricated elements in r.c. constitute the classic three-hinged arch with horizontal thrust/loads absorbed by the hinges (it was actually an evolution of the Varese beams, which were also proposed with curved profile). These elements allowed to the creation of spans between 10 meters and 30 meters. In the first version, hollow clay tiles were placed within the arches and the roof was completed by concreting.

This system evolved with the introduction of prefabricated truss arches in r.c. (usually with a parabolic profile) characterised by triangular-shaped voids present throughout the element; the hollow clay tiles were later replaced by U-shaped elements in r.c., whose greater length (1.2 m - 2.5 m) allowed wider interaxes and thinner arches. The speed of assembly of the system was determined by the possibility of lifting and placing the semi-arches directly on the perimeter walls and using only one mobile scaffold at the centreline. The waterproofing layer was made usually with cement-bonded sheets (asbestos cement) and an insulation layer. In the same period, the r.c. trusses of trapezoidal shape were developed and introduced[34].

Concurrently, other forms and types, used in both industrial and agricultural buildings, were proposed by other producers: for instance the frame system based on open-L components (more than 90 degree wide angle) that were functioning simultaneously as pillars and beams. The saw-toothed roof elements were also introduced as r.c. products, even in the 'multiple shed' version (F. 1-55, F. 1-56).

The use of prestressing through pretension began in the second half of the '50s in Italy too for industrial constructions, originating from the German patent for the Silberkuhl prestressed slab (marketed in Italy since 1956). I-shaped beams and Y-shaped beams, of various heights, were proposed. The Y-beam, in particular, was highly successful because of its low cost (and the possibility of completion with simple asbestos cement sheets) and its dual function as drainage of waters, favoured by the Y-shape and the curved profile given by prestressing.

In the early '60s two more roof elements in prestressed r.c. were introduced, marking the turning point of prefabricated structures for industrial building, in which finally the structural rationality was merged with material savings and handling costs: the double slope beam and the double-T beam.

The well-known double-slope beam (inclining from 10% to 12%) was imported from Germany. It was initially proposed in several standard length (from 12.4 meters to

[34] Relevant producers of these components are reported by Lavizzari (2006a): Astori as the first producer of open-L components, RDB as the first producer of double-slope beams, and others such as SCAV, VARAC and Gianese.

14.4 - 16.4 - 18.4 and 20.4 meters, with fixed distance of 6 meters), later abandoned in favour of customization.

The roof slab was introduced as a roofing element for industrial building, prestressed, prefabricated, self-supporting and resting directly on the bearing structure. The best known version of the prestressed roof slab is the Pi-beam (or double-T beam), with variable thicknesses and span up to 10 meters, with a standard width of 250 cm, used both as a completion element and as the main element of the roof and, in some cases, as a cladding element.

In addition, in the late '60s, experimentation on precast prestressed r.c. roof components continued, leading to several interesting outcomes. Favini too proceeded with tests to devise and patent (1967) a curved element called "Coppone AL.FA". The element sums up the techniques of prestressed concrete and of the thin-shells, performing static functions for span up to 30 meters together with water drainage functions, and can be assembled without further processing. In this sense, it was the progenitor of those systems still in use for the roofing of prefabricated industrial buildings (Barazzetta, 2004).

Together with the development of precast concrete beams, also vertical structure evolved in precast r.c. pillars and the bearing structure became a concrete skeleton, understood as an entirely prefabricated system (F. 1-57).

The last element - chronologically speaking - to complete the system was the precast concrete wall panel. The first applications of prefabricated wall elements in reinforced concrete originated - probably at the same time - from the idea of using the double-T slab placed vertically on the external perimeter of the building (Koncz, 1969).

In the late '60s, the horizontal panels (i.e. horizontal laying) were aldo introduced; they were fixed to the bearing structure through simple grooves (i.e. they were embedded in the pillars as used for concrete fencing). Only later, in the '70s, when metal extrusions with omega sections were adopted, could the panels be connected to the external side of the pillars (Lavizzari, 2006a). Additionally, still in the '70s, due to increasing attention to environmental issues and energy-saving, sandwich panels with insulation layers were proposed.

Issues of modularity in prefabrication for industrial buildings

As prefabricated components in reinforced concrete were widely adopted, research for the definition of standard industrial building types led to the specification of several fundamental types, according to the number of spans and storeys (F. 1-58).
Concurrently to this development, the issues of modularity and dimensioning, according to their relevance for prefabricated construction, were being explored with a specific focus on industrial building types[35]. On the basis of the prevailing dimensions of the production facilities, the structural grid of the building was standardised on the measures of 20 meters or 12.50 meters, according to the span of available beams and the maximum building height of 10 meters or 20.00 meters (Neufert, 1965).
If, on the one hand, modular values were proposed and adopted for wall panels, mainly related to the residential sector (Grisotti, 1968; Mandolesi, 1978) and based on the module of 1 meter, on the other hand, different measures of the module-object, usually represented by the panel, were chosen for the industrial building sector (F. 1-59). The base module was defined mainly on the basis of transport requirements (maximum size of the container or trailer), alternatively as the greater multiple of the meter[36], and then 2 meter, or the maximum transportable size, and then 2.50 meters (F. 1-60). This definition of basic dimensions also took into account the transverse stresses in the stripping and assembly of precast concrete elements as well as the economy of transport and the ability to carry multiple items on the same vehicle. This is why the producers of precast concrete components progressively oriented the size towards sub-modules of 2.50 m for the non-structural elements. Furthermore, in the building analysed in the following paragraphs, high dimensional variants were detected: original prefabricated systems or components were designed upon modules of 1.20 m, 1.25 m, or 1.50 m, corresponding to the width of the panel which constitutes the module-object, on which the dimensional grid of the entire building is based. Only the thickness was subsequently normalized to 16 cm, 20 cm, or 24 cm (plus an insulation layer of custom dimension).

In this sense, at a time when, even in Italy, especially as regards interest for the industrialization of building and prefabrication, the matter of modular coordination became central, industrial and commercial constructions remains, in a way, excluded from the discussion of the most relevant figures committed the topic (Ciribini, CNR).

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[35] The basic module for the industrial building sector was the IBM - industrial building module. It was initially introduced in the German context and was based on the octametric system (10 times the unit 25 cm) and, as a result, the IBM of 2.50 m was translated in the standards measure of spans for industrial buildings, established by the DIN standards (Koncz, 1969).

[36] In the European countries which had adopted - at that time - the international module of 10 cm, the regulation and the practice partially deviated from this standardization, preferring measures of 60 cm - 120 cm - 240 cm etc. for industrial buildings.

Several authors point out, in fact, that, already in the ‘70s, despite the interesting results in terms of quality and quantity of production, attempts to modularly coordinate the production of prefabricated construction were totally unsatisfactory (Corsini, 1972). Moreover, at the end of the '70s those limitations, particularly with regard to a coordination of modular and other standards in the sector, still existed and were very probably destined to continue due to government inertia and also the somewhat short-sighted outlook of many manufacturers (Biondo and Rognoni, 1976g).
In fact, while in other countries the unification approach to modular coordination had already led to a significant evolution towards open prefab systems (with the "Component approach" in Great Britain and "System components design" in the USA), in Italy an actual overcoming of the closed system of prefabrication never occurred. Despite the mass production of "turnkey" single-storey industrial building had turned out as an opportunity to overcome the ‘closed system prefabrication’ (Mandolesi, 1994), the possibility of building by putting together precast products from different companies was never fully realised.
Instead, in Europe and especially in Italy, the incentives by public authorities to promote the development of industrial areas led to the production of "standard industrial buildings" to fit the demand in an articulated and differentiated way, through a sort of "open prefab systems". In this sense, the possibilities were related to the availability on the market of components exploitable for multiple solutions (building plan, volume and façade). The skeleton structure was meant as the modular pattern upon which to coordinate the roof elements and the façade panels, which generally had different characteristics to better meet both the functional and formal requirements of the customer. This led to prefabricated systems which allowed alternative solutions, both for roofing and cladding and for the shape and the finishes, using different techniques and materials, but remaining however within the same company's catalogue (Mandolesi, 1994).
The reasons for the impediment in the evolution of open system prefabrication lay principally in the fact that the constructions sector ended up mainly to the development of closed systems with modular solutions *ad hoc*. Furthermore, many companies, even if aiming to provide a complete product ‘turnkey’, came to specialize in the production of some specific components (i.e. only bearing structures or only a façade elements); thus the lack of modular coordination turned out to be more limiting exactly in those cases. Although in the '80s prefabricated systems seemed close to becoming open systems, since many connection problems between different building elements had been solved, it was individual companies who actually dealt with the problems of coordination (Nardi, 1986), which was still understood as the management of different specialised producers rather than a proper integration of components measurements.

Precast concrete panels for industrial buildings

In general, prefabricated industrial buildings initially consisted of a limited number of component types: columns, beams, roofing slabs and cladding panels. As the component types were not many, even the connection or joint problems were clearly identifiable and limited, thus solutions and combinations are characterised by great redundancy (Corsini, 1972).
The basic components of this type of industrial building are nowadays the same precast concrete units: columns, beams, floor/ceiling slabs, walls and façade panels, while foundations are usually site-prepared. For instance, according to the type of roof, such as pitched roof, flat roof, prismatic and curved roof, cantilevered roof and tensile structures, prefabricated concrete beams were offered in various versions: V-purlin, rectangular, flanged, L-beam, T-beam, I-beam etc. Ceiling and flooring elements vary from double T-slab to solid floors (thickness standardised in 12 - 15 - 18 cm) and hollow core floors (thickness 18 - 20 - 22 - 26 - 32 - 40 cm).
All the components were generally produced off-site in the manufacturing plant, but for relevant building programmes or specific design requirements they might also be produced on-site.

As precast concrete structures were introduced, the issue of cladding elements arose and led to the definition of specific solution for precast concrete wall panels. The panels, initially devised as simple load-bearing components, gradually diversified according to their scope. Since their earliest application (Koncz, 1969), precast concrete panels have been characterised by a large number of different typologies, depending on their structural role (bearing panels, stiffening panels, cladding panels), their horizontal or vertical laying, their material features (special cements, exposed aggregate finishing, decorative surfaces, insulation layers), and their formal features (flat panels, ribbed panels).
However, a diverse heterogeneity of the element has also been noted in the Italian context in regard to the very nature of the constructive systems based on independent bearing skeleton: on the one hand it allows a high distributive-functional flexibility, and on the other the possibility of alternative solutions for the cladding. In addition, the various types of cladding panels evolved and spread according to market demand, the specialisations of the manufacturing companies, and the available customisation solutions.

Precast concrete panels can be distinguished, according to their static function, as:
- bearing panels;
- stiffening panels;
- cladding panels.

For industrial construction, formerly the vertical panels were bearing elements, while horizontal panels can be considered stiffening elements, if assembled between the structural skeleton (pillars), or cladding elements, when anchored on the external side of the structure (pillars).

The material composition of the panels varied according to their purpose:

- solid slabs/panels in standard concrete and later in lightweight concrete;
- hollow panels with various cross-section compositions of one or more layers;
- sandwich panels with an insulating layer; the first solutions, in the '70s, to improve the thermal performance of the panels envisaged the addition of an insulating layer - variously extended - inside the panel or the use of special aggregates. After several experiments, the chosen solution was - and remains today - an insulating layer (different available thickness) placed within the panel, interrupted at 20 cm - 25 cm from the edges (Lavizzari, 2006a).

Precast concrete panels can lay horizontally or vertically, creating different types of wall[37]. Vertical panels were formerly bearing wall elements, and later also simple cladding (F. 1-62, F. 1-63). This type of panels eased the integration of doors and vertical windows inside the panel, allowed more possibilities for the cross-section shape (ribbed, trapezoidal and curved) and external finishing, and could have both bearing and stiffening functions.
Horizontal panels originated from the assembly principle used for precast fences - panels were inserted between the pillars. The horizontal laying eased the combination with windows in other materials as both autonomous components (such as ribbon windows) and elements integrated in the panel (F. 1-64, F. 1-65). However, it presented problems in the assembly (if the span exceeds 8 m span) and less choice for the cross-section of the panels (only flat or ribbed).
In the case of multi-storey buildings, the distinction between vertical and horizontal panels was the same but there were even fewer possibilities of combination and cross-section shapes, due to problems of jointing and connection with floors.

The types of precast concrete panels used in industrial building could be distinguished by their formal and material features, and especially by their shape and cross section.
While the internal face of the panels - facing inwards - was usually forcedly flat and could be completed by an interior insulation layer or various finishing materials, the external face of the panel could be characterised by ribbing and protuberances or special surface finishing.
Flat panels were intended to create simple walls and were often preferred because of the possibility of using customised dimensions and corner solutions.
Ribbed panels were intended to create ribbed walls with unique three-dimensional and aesthetic features (F. 1-66, F. 1-67, F. 1-68). Ribs were usually along the edge or

[37] The following description of the types of panels and their main features in the late '60s is referred to the handbooks and technical publications on prefabricated systems for industrial buildings (Koncz, 1962; Koncz, 1969; Giay, 1964) an subsequent publications.

the middle line of the panel, but they could also be customised. The choice of the ribbing may have also aesthetic implications, for example concealing or underlining the joints. However, ribbed types made solutions for corners and windows more difficult.
Other special cross-section panels were used, mainly in the past, combined with special-shape roof elements. Prismatic and curved concrete components rest on the principle of strength through shape (as is the case of prismatic cross-section elements used in the Benetton factory by Scarpa).

One of the early production and assembly systems, introduced in the first years of the twentieth century (1906) in the USA, was the tilt-up technique: wall elements were pre-cast on-site, directly on the ground through side formworks, and then lifted - rotated (F. 1-69). In Italy, on the other hand, prefabrication on site - with standardised forms - was often used for particular building programmes; however, the production process generally adopted in precast plants consists of a forming system with reusable metal forms or lamination lines (F. 1-70).
The assembly method depended on to static function of the panels. Bearing panels were embedded at the base in the foundations and the system was quite quick[38] - 15 minutes - but showed alignment problems and required a finishing cast for fastening panels and sealing joints. Cladding panels, instead, were fastened to the structure, the assembly was quicker and in two phases: panels were lifted and placed close together against the beams, then they were aligned and bolted to the structure (F. 1-71, F. 1-72).
Horizontal panels required longer assembly - 15-20 minutes for each element - because connections were to be made after the placement of each panel (F. 1-73, F. 1-74).

According to these basic types and their evolution, considerations can be made about the specific use and some particular versions of the panels. The ribbed vertical panels, for instance, were introduced as load-bearing elements, intended mainly for single-storey industrial buildings with a single aisle. The need for structural strength and the simple assembly favoured the introduction, for this type of panels, of many shape and cross-section options. This is why the cross-section might consist of ribbed plates (T, U, double-T slabs) or prismatic shapes (trapezoidal, triangular) or curved shapes (concave or convex), being also associated with the concept of 'thin-shell structures' based on the strength-through-shape principle. These particular shapes, however, implied specific issues regarding jointing and connection as well as finishing (adding internal or external insulation layer) and complication in the integration of doors and windows (the only possible solution was to alternate panels and window elements).

[38] The assembly methods and times are referred to the '60s as reported by Koncz (1969).

Various solutions were possible for completing the corner of the building, according to the ribbing or cross-shape of the panel and to the modular organisation of the façade. Later special 'corner components' were also introduced.

The connection system too depends upon the type of panels and their static function: the former load-bearing vertical panels were usually embedded at the base in the foundation and, according to their actual shape, fastened with a completion cast or with metal anchorage.
In structures built with ribbed or prismatic-shape cross-section panels (for both the walls and the roof), the connections were always to be made by dry connection systems of bolts and metal anchors. The connection systems for non-load bearing panels were formerly usually made up of metal anchors, whether the panels were placed within the pillars or outside the structure as cladding elements.
The joints were sealed with filling and waterproofing materials (mastic, resin, synthetic rubber - neoprene, etc.), sometimes moulded to accommodate the panels edges. Even in the early stage of development, the design of the joints, especially the horizontal ones, was particularly accurate, as fundamental to prevent water penetration.

Concrete mix and finishing for precast panels may vary according to design purposes.
The use of white concrete, for instance, began quite early. This type of concrete, obtained through the use of white cement[39] and aggregates of light colour, allowed to the production of well-finished products directly from the formwork. On the other hand, the light colour of components might highlight the presence of different shades (due to improper mixing or aggregates) and surface cracking or lead to quicker stains and discoloration.
Lightweight concrete was used in concrete panels from the ‘70s onwards and was generally achieved by adding or replacing normal aggregates with lightweight aggregates (such as expanded clay or calcined schists). Since its introduction it has proved particularly suited to prefabricated construction, for both structural and non-structural uses, with the side effect that the strength might be reduced.

The surface finish of the panels is mainly related to the production process: different concrete surfaces depend on whether the concrete is cast in a particular formwork or the surface treated after maturation. Some surface finishing of the panel was obtained directly from the formwork while other finishing was obtained with subsequent processing, which is based on the internal composition of the concrete cast, such as the formation of a surface ‘skin’ characterized by the concentration of fine aggregates and cement.

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[39] The white colour of the cement depends on the iron deficiency, which gives a grey colour to the standard Portland and a darker grey to ferric cement. Technical information on the past and current uses of white cement in Italy are available on www.italcementi.it.

In the design of fair-face concrete elements, a type of surface finishing which became a remarkably widespread was exposed aggregate concrete, in which the surface is characterised by the exposure of the greater size particles of the aggregate of the concrete mix, crating a surface pattern characterized by the presence of gravel or small stones. It is produced by removing the first layer (skin) of the concrete immediately after the disassembly of the formwork, through various possible procedures: the use of retardant spray and washing water jets, the use of retardant paper and washing water jets or the addition of a layer of fabric with gravel.

Particular shapes and surfaces could be obtained through the use of formworks or special moulds. On the one hand, the choice of the material for the formworks influences the results: wood formworks might promote effects of material absorption, while steel and plastic formworks might favour the formation of blow-holes. Ribbed shapes and textures were usually obtained through plastic or glass-fibre formworks; additionally, special textures and reliefs are obtained with the introduction of three-dimensional elements - rubber, plastic, steel - inside the formwork (F. 1-75, F. 1-76).
Other formal experiments on special surface finishing were observed in concrete decorated with bas-reliefs and special textures, created through special plastic moulds. In those cases a specific protective covering, to be removed only after the assembly, were used (Del Lago and Cislaghi, 1977).
Other aesthetic features might be obtained through the use of pigments in the concrete mix, such as iron oxide for red, yellow, and brown shades, chromium oxide and hydrated chromium oxide for green shade, cobalt, aluminium, or chromium oxide for blue shade. However, stability over time and non-interference with the hydration process are required.
Coatings and paintings are usually applied after assembly and can be carried out through the use of coloured paints or special paints including aggregates. Protective coatings include epoxy resins, tar-based epoxy resins, polyurethanes or other layer of plastic materials and tiles).
Surface finishing of concrete can be carried out by hand, with a pointed tool, rough finishing or ‘Brocatello’ finishing, with a bush hammer or with a chisel. Other possible surface mechanical finishing, carried out during the manufacturing process or after it, includes: sawing, sanding, smoothing and polishing (F. 1-77, F. 1-78). Finally, special surface effects can be obtained through blasting (sand, steel shot, corundum, or water and sand), flaming and washing (with normal or fine water or with acids).

F. 1-41: Remmert cotton mill in Ciriè, Turin, I, 1900, Hennebique system (Nelva, 1990)

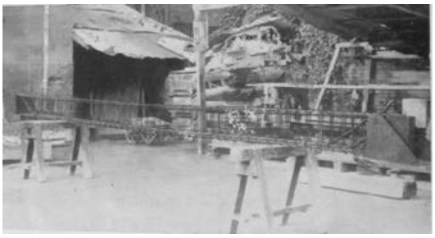
F. 1-42: Remmert cotton mill in Ciriè, Turin, I, 1900, Hennebique system (Nelva, 1990)

F. 1-43: Usine de la Société centrale des alliages légers,, Issoire, FR, A. Perret, 1939-1940 (archiwebture.citechaillot.fr)

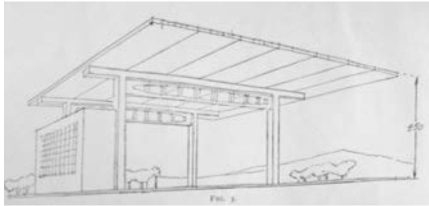
F. 1-44: Usine de la Société centrale des alliages légers,, Issoire, FR, A. Perret, 1939-1940 (archiwebture.citechaillot.fr)

F. 1-45: Salt warehouses in Tortona, I, 1951, P. L. Nervi (Modica and Santarella, 2014)

F. 1-46: Salt warehouses in Tortona, I, 1951, P. L. Nervi (Modica and Santarella, 2014)

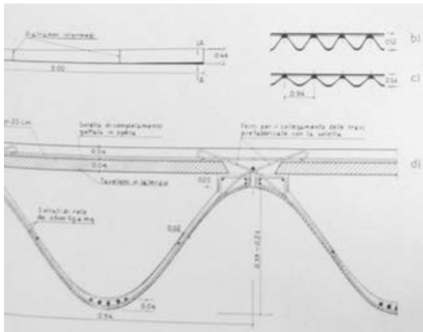


F. 1-47: serial production of precast concrete components in the late '30s (Rabbi, 1939)

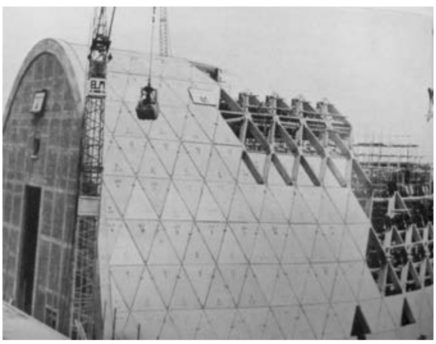


F. 1-48: suggestions for the serial production of precast concrete components in the late '30s (Rabbi, 1939)

F. 1-49: “Giovanni Agnelli Hall”, Torino, 1948, P. L. Nervi (Giay, 1964)



F. 1-50: section of the “Giovanni Agnelli Hall”, Torino, 1948, P. L. Nervi (Giay, 1964)

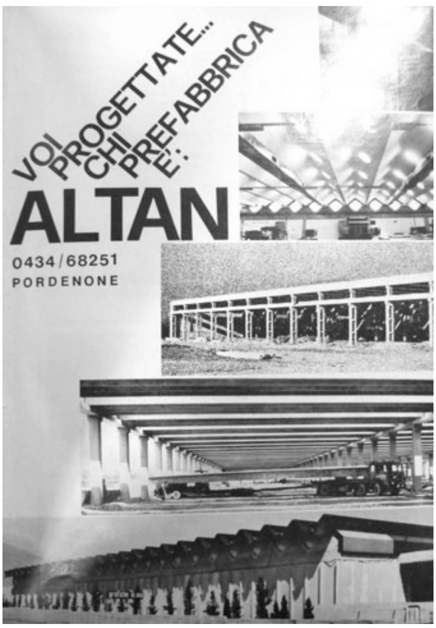


F. 1-51: industrial building in Berlin from the early ‘60s, precast concrete special panels (Artigliere and De Santis, 1964)

F. 1-52: industrial building in Berlin from the early ‘60s, precast concrete special panels (Artigliere and De Santis, 1964)

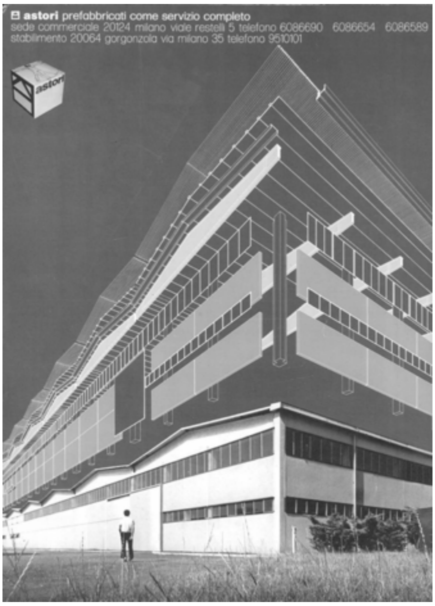
F. 1-53: precast concrete elements for vaulted roofs of industrial buildings, advertisement in the 60s (Rassegna Tecnica FVG)

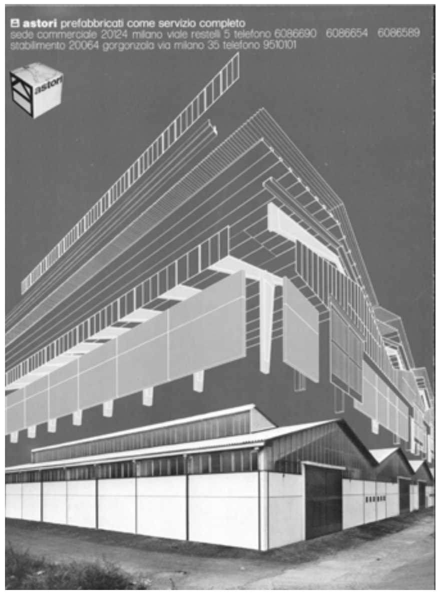
F. 1-54: precast concrete elements for vaulted roofs of industrial buildings, advertisement in the 60s (Rassegna Tecnica FVG)

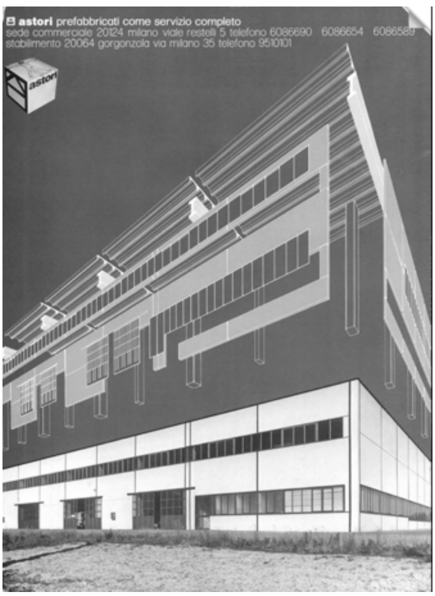


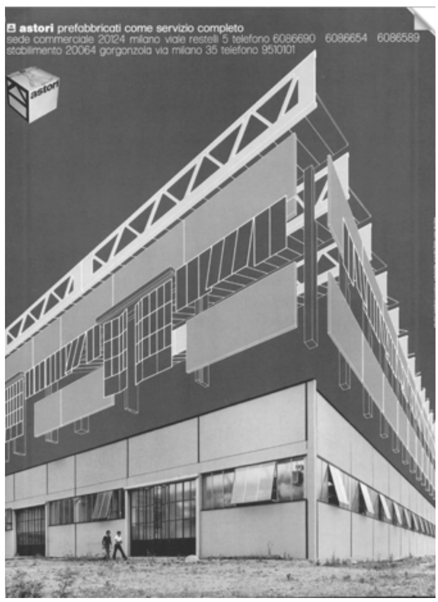
F. 1-55: precast concrete elements for industrial buildings, ALTAN advertisement in the late '60s (Rassegna Tecnica FVG)

F. 1-56: precast concrete elements for industrial buildings, ASTORI advertisement in the late '60s (La Prefabbricazione)

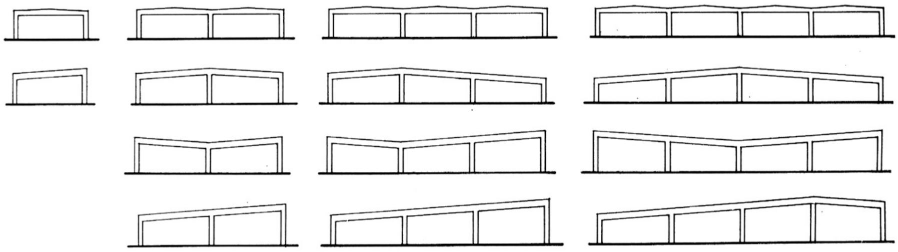




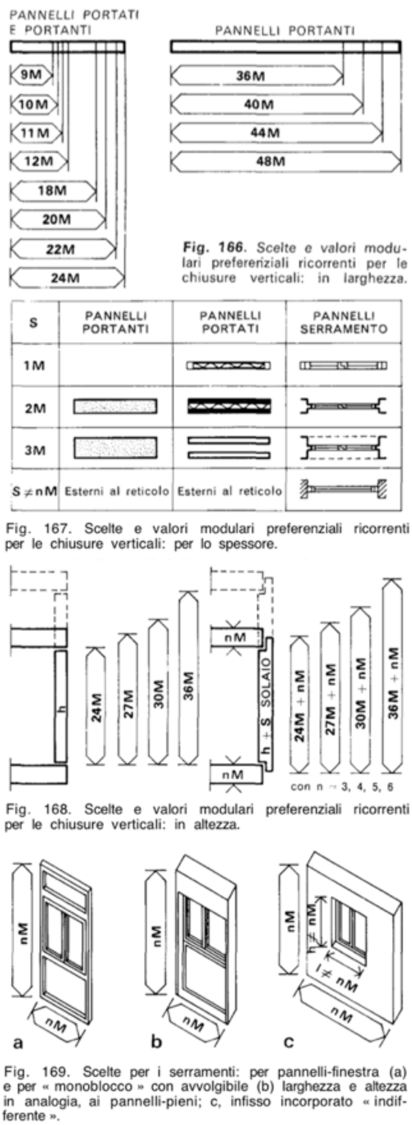




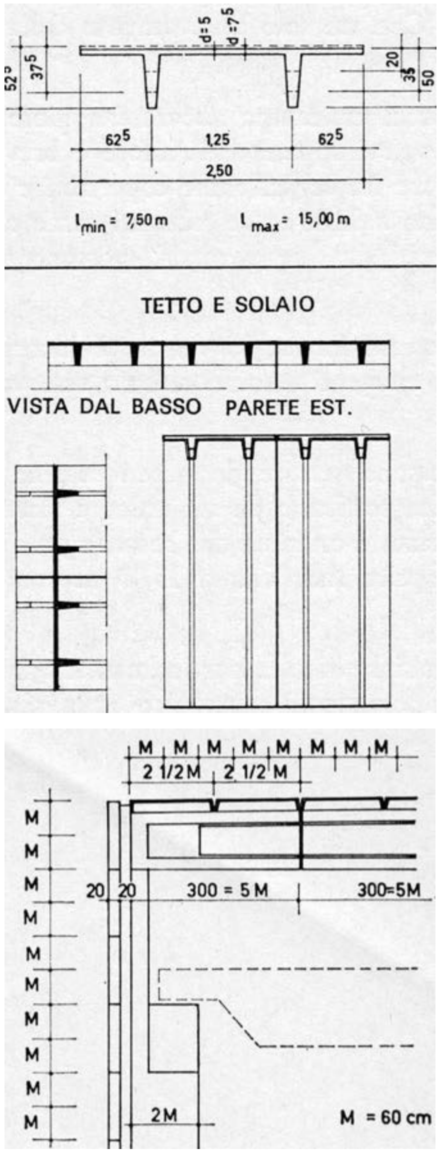
F. 1-57: precast concrete systems for industrial buildings, series of advertisement by ASTORI in the 70s (advertisment section on Domus 1978)



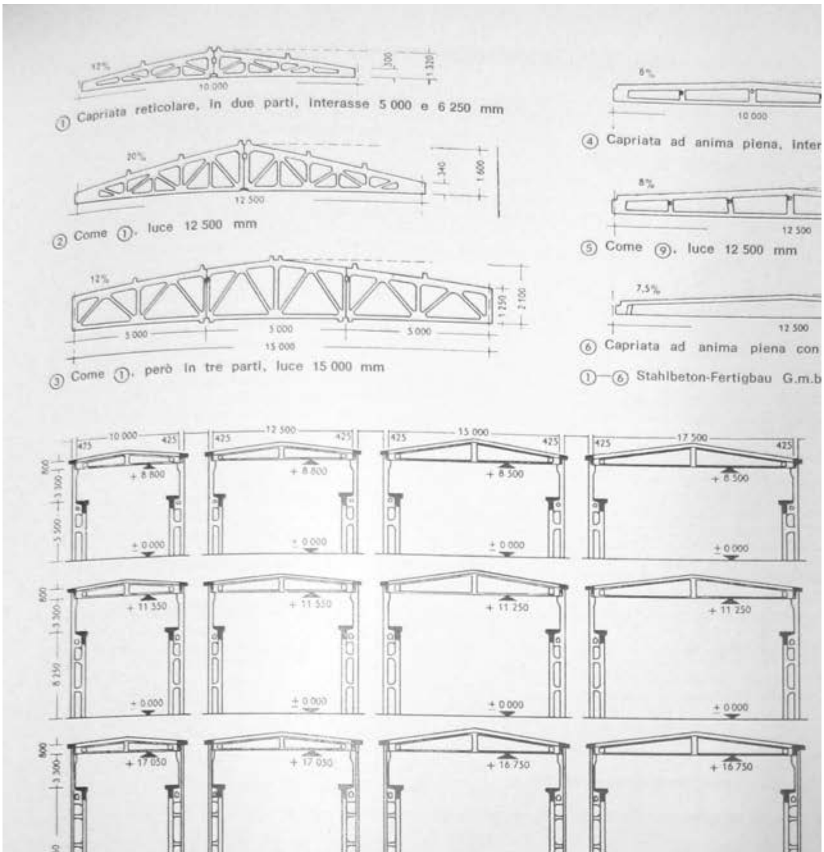
F. 1-58: basic industrial building types according to the number of spans and the type of roof (Koncz, 1969)



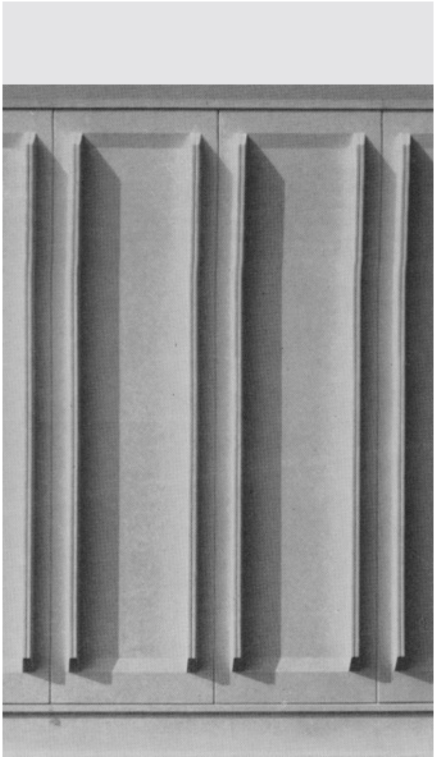
F. 1-59: modular dimension for façade elements, mainly referred to residential constructions (Mandolesi, 1978)



F. 1-60: standardisation of components and measures for the industrial building sector (Koncz, 1969)

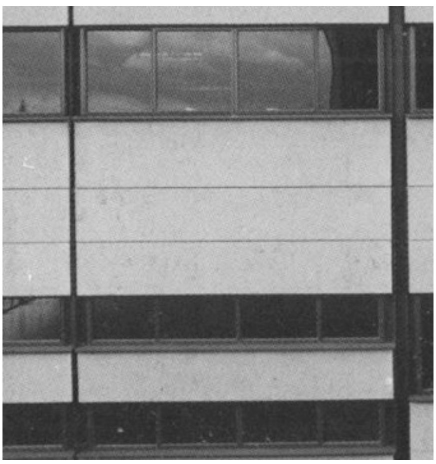


F. 1-61: standardisation of industrial buildings and possible modular solutions (Neufert, 1965)

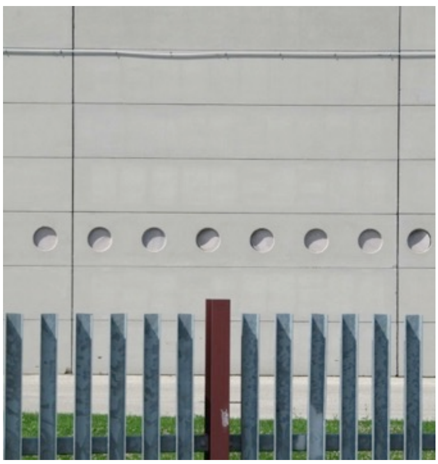


F. 1-62: precast concrete panels, vertical, ribbed (Cislaghi, 1977)

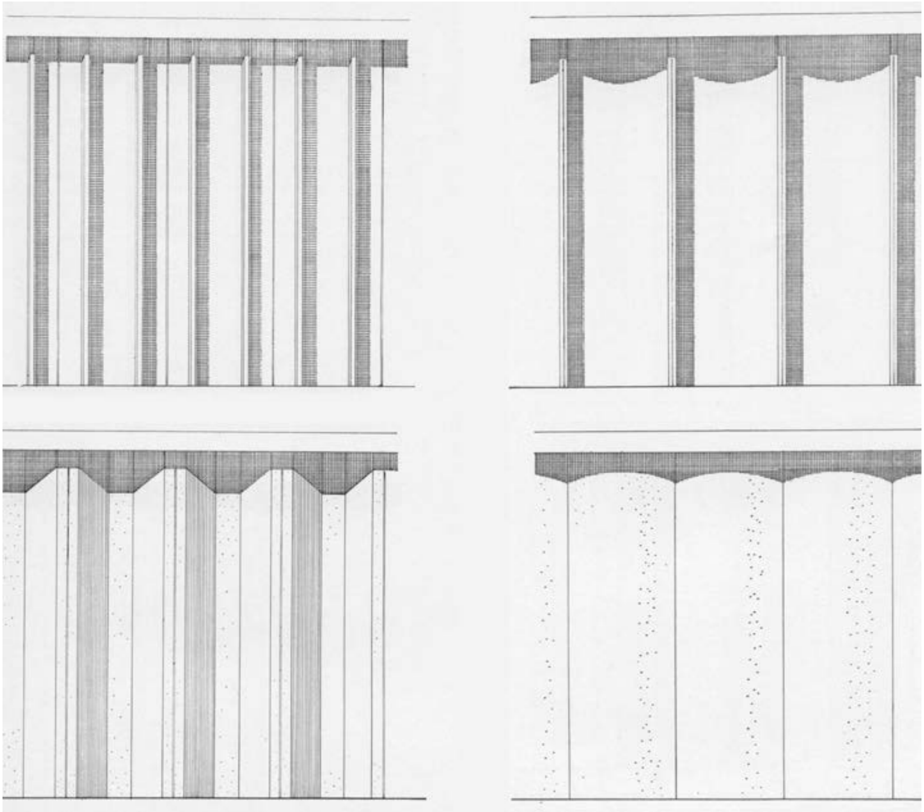
F. 1-63: precast concrete panels, vertical, ribbed, integrated windows, Solari factory in Udine (author, 2014)



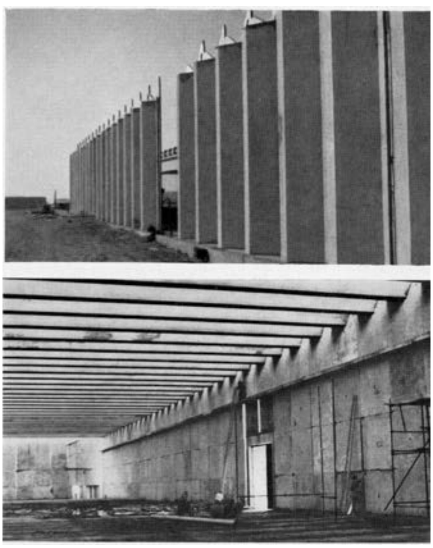
F. 1-64: precast concrete panels, horizontal, flat, ribbon windows (Croset, 1989)



F. 1-65: precast concrete panels, horizontal, flat, integrated holes (author, 2014)

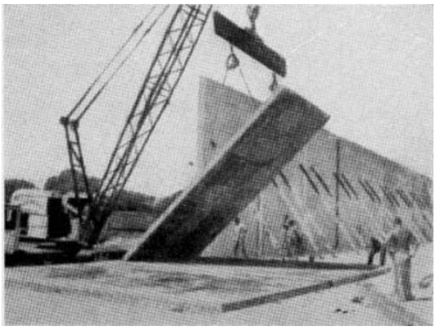


F. 1-66: precast concrete panels, prismatic shapes (Koncz, 1969)

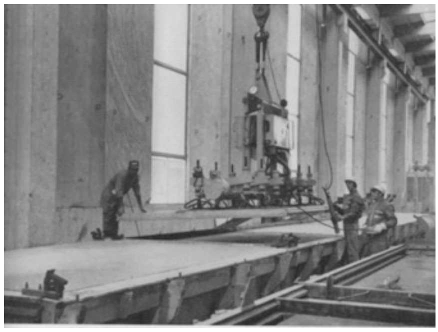


F. 1-67: precast concrete panels, prismatic shapes (Koncz, 1969)

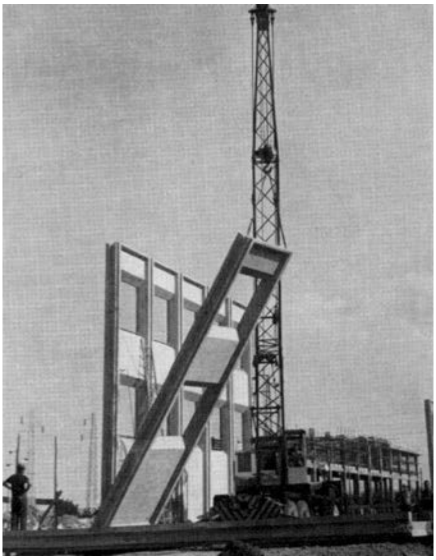
F. 1-68: precast concrete panels, special cross-section, precast plant in Verona (author, 2014)



F. 1-69: Tilt-Up prefabrication on-site (Koncz, 1969)

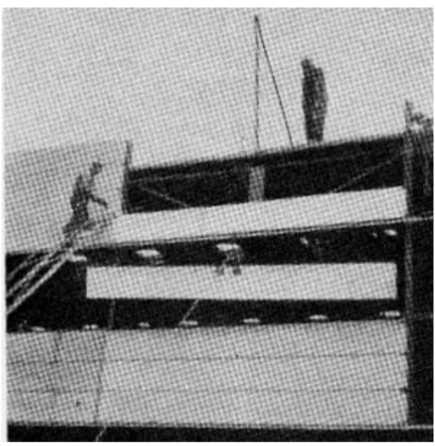


F. 1-70: prefabrication in precast plant, lamination system (Koncz, 1969)

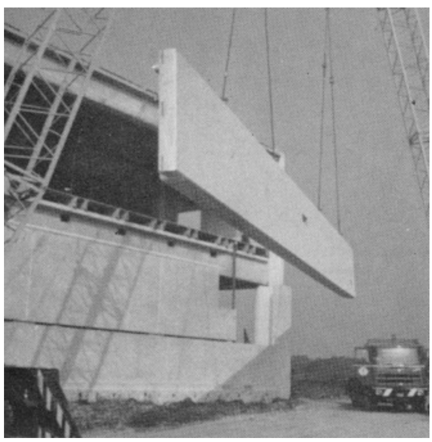


F. 1-71: assembly of vertical load-bearing precast concrete panels (Koncz, 1969)

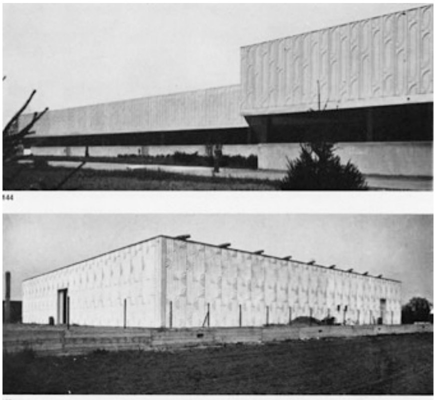
F. 1-72: assembly of vertical cladding precast concrete panels (Cislaghi, 1977)



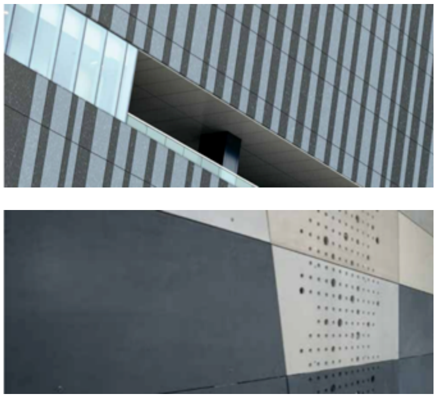
F. 1-73: assembly of horizontal panels (Koncz, 1969)



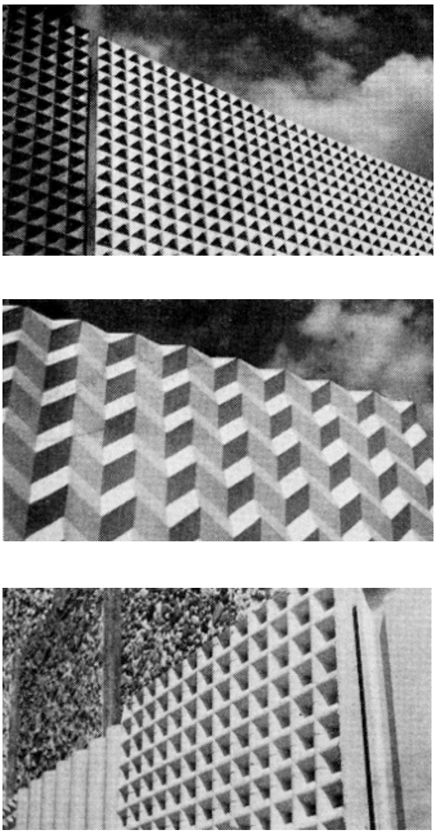
F. 1-74: assembly of horizontal panels (Cislaghi, 1977)



F. 1-75: decorative concrete surface produced in the ‘70s by PRECEM (Cislaghi, 1977)



F. 1-76: current possibilities of surface finishing for precast concrete (Zanette Prefabbricati catalogue, 2014)



F. 1-77: special surface finish for precast concrete elements in the '60s (Koncz, 1969)

F. 1-78: concrete surface finishing, coloured concrete, exposed aggregate concrete (Tognon, 1980)

1.2 A database for understanding and documenting concrete and prefabricated industrial architecture

The phenomenon of the abandonment of industrial buildings and sites has made the reuse of industrial heritage, at various scales, a major topic of current post-industrial dynamics in many European countries. The evaluation of industrial heritage and an understanding of the history of the technology and processes predominant in the local area enable the identification of valuable buildings, which may then assume the role of potential centres for the re-design of suburban areas and landscape. This presence of 'modernist' buildings increases the need for strategies for their protection and transformation, in accordance with the principles of selective preservation and adaptive reuse (paragraph 1.2.1).

Industrial architecture in Italy has largely concentrated upon concrete construction techniques, mainly through the evolution of prefabrication, which also played an important role in the diffusion of the industrial building types which today constitute the diffuse and fragmented landscape of small and medium-sized enterprises. Consequently, between the '50s and the '70s, many Italian designers experimented with the use of concrete elements in industrial construction: several of them took the opportunity to introduce new technologies and brand-images by designing their own precast concrete elements, while others exploited the possibilities presented by prefabrication and standardisation to inject their personal modernist language into industrial architecture.

Recognising that the identification of examples of emergent industrial architecture is, above and beyond any kind of intervention, a much-needed step towards 'critical knowledge', research into the issue has produced a catalogue of "Concrete industrial architecture in Italy: 1950-1980" (paragraph 1.2.2), which lists notable buildings constructed using both cast-in-place and pre-cast concrete methods, as well as architects and companies operating in the field (paragraph 1.2.3). The records included are organised upon the basis of a *minimum fiche* (as defined for the Docomomo Register) in a database which includes around 120 well-known industrial buildings (paragraph 1.2.4) and about 20 case studies (paragraph 1.2.5) and which also proposes possible future implementations. The database provides an overview of Italian industrial architecture and highlights some of those unique aspects - such as adaptability, standardisation, industrialisation and, above all, experimentation - which are deserving of conservation. This system is able to track the use and condition of buildings over time by recording information on the current activity taking place in the facility and monitoring their state and any possible damage.

It is an approach which therefore favours an organic evaluation of the values and characteristics of the selected buildings in order to assess their adequacy and potential for legal protection or reuse, so that new, innovative initiatives may be proposed for their transformation into meaningful structures and landmarks of a re-designed territory which, however, pay due respect to their history.

1.2.1 Documenting modern and contemporary industrial architecture

In recent years, in the national context, many institutional and research activities have focused on modern and contemporary architectural heritage, producing catalogues of works, which therefore includes remarkable industrial building. These catalogues constitute a basic reference for this study and favour the comparison between and the discussion of the identification of valuable buildings and the identification of adequate selection criteria.

Catalogues and relevant research studies in Italy

The census of Italian architecture of the late twentieth century, *Censimento nazionale delle architetture italiane del secondo Novecento* began in 2000 by the MiBACT[40]. The selection of architectural works was guided by an assessment grid based on bibliographical and historic criteria; a bibliographic review considered the ‘critical success’ of a work, such as citations in specific publications and recognised national and international value, while the historical-critical criteria examined elements related to the architectural history, the cultural debate, the significance of the work in the context, the relevance of its author. In addition, the acquisition of data was also conducted through surveys and examination of archival documents. The result is a catalogue of buildings divided into three main categories: excellent works, selected works and recent works. The catalogue also includes regional sections, such as the survey on architecture in Lombardia, Veneto, Friuli Venezia Giulia and Trentino, carried out by IUAV, and Rome, by University of Rome, and other regional catalogues[41].

Relevant research on modern architecture, in Italy, has also been carried out by IUAV with the *Atlas of Italian architecture of the '50s and' ‘60s: figures, forms, construction techniques*[42], consisting in a sizeable catalogue which also includes many works of industrial architecture (about 50). Begun in 2008, the atlas presents detailed information on building type, structural type, building system, designers and

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[40] The activity of the Ministry of cultural heritage regarding contemporary architecture is presented in www.aap.beniculturali.it/censimento.html; the online database of the works is available at architetturecontemporanee.beniculturali.it.

[41] Lombardia (www.lombardiabeniculturali.it/architetture900/), Veneto, Friuli Venezia Giulia and Trentino, carried out by IUAV, and in Rome, by University of Rome; (Casciato and Orlandi, 2005; Aleardi and Marcetti, 2011; Palestini and Pozzi, 2013).

[42] The Atlas of Italian architecture of the '50s and' ‘60s: figures, forms, construction techniques is available online at atlante.iuav.it.

construction companies, favouring a comprehensive understanding of the specific built heritage.

The *SIXXI - Twentieth Century Structural Engineering: The Italian Contribution*[43] project, carried out by the Tor Vergata University of Rome, focuses on the history of Italian structural engineering of the twentieth century. The study, begun in 2011, illustrates the overall sequence of events and major works in order to revive the now-vanished figurative universe of modern engineering (Poretti and Iori, 2014; Poretti and Iori, 2015a; Poretti and Iori, 2015b) and aims to identify significant works for structural engineering history and to propose guidelines for their preservation and maintenance.

The *ITER project for the promotion of tourism of modern architecture*[44] proposes a catalogue of remarkable modern buildings across Lombardia, Emilia Romagna, Liguria and Piemonte in the format of itineraries, also promoting direct knowledge and visits of these spaces. The catalogue includes about 160 buildings, of which several industrial facilities.

In recent years, many other interesting projects have been dedicated to notable buildings, authors, or specific industrial building types or geographical areas.

The project and exhibition *The Remnants Of A Miracle* at the 14th Venice Biennale[45] presented some masterpieces of Italian modern architecture which are now neglected and abandoned; the majority of the building presented are indeed former factories.

Another interesting recent study focused on industrial warehouses with a parabolic structure (Modica and Santarella, 2014), presenting hundreds of buildings of this type, built between the ‘20s and the ‘70s in Italy. These particular industrial buildings are characterised by majestic ribbed vaults in reinforced concrete which earn them a respectable role in industrial architecture linked to the Modern Movement and serial production. From this work of systematic documentation and cataloguing of a specific type, it is clear that the presence of a serial heritage, little known, is associated to the emergence of remarkable buildings such as the works of Pier Luigi Nervi or the Paraboloide of Casale Monferrato (Ramello, 2013).

The Fondazione Aldo Favini[46] created in 2014 to promote research and education in structural engineering and architecture, presents, in the form of an online catalogue, the works realised by the author (sometimes in collaboration with other notable figures) between the '50s and the '90s, including some of the most interesting examples of Italian industrial architecture.

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[43] The SIXXI research project, the most influential studies currently being carried out in the academic field of Architectural Engineering, is founded by the ERC Advanced Grant 2011 (Sergio Poretti); www.tulliaiori.com/SIXXI/.

[44] The ITER project is available online at www.architetturadelmoderno.it.

[45] The exihibition and the project curated by Luka Skansi and presented at the Venice Biennale 2014, www.behance.net/gallery/17326915/The-Remnants-Of-A-Miracle.

[46] www.fondazionefavini.it.

The research project *Forms and Structures*[47] explores the design culture of the fifties and sixties from a historical perspective with particular emphasis on hybridization between engineering and architecture.
Furthermore, a recent contribution to the field of study was added by the study *Prefabricated Industrial Architecture in Italy* (Albani, 2016), presented at the 14th Docomomo international conference in Lisbon.

The most important reference in the field is the activity of Docomomo (Do.co.mo.mo - the International committee for the Documentation and Conservation of buildings, sites, and neighbourhoods of the Modern Movement), which is strongly based on the documentation process[48].
The International specialist committee on Registers (ISC/R) was introduced in 1992 (Dassau Conference), aiming to produce an inventory of emblematic examples of modern architecture and define a grid of selection criteria. In 1994 (Barcelona Conference) the first 500 buildings and sites were selected, and three levels of selection were defined: the local level, as an open inventory based on national or regional scale, the international level, which include the international selection (IS) of building/sites, and the global level, for the UNESCO World Heritage List. In 2000 a new NIS fiche (New International Selection) was published: it was designed to accommodate a greater number of objects - especially complexes - and to facilitate the inclusion of the record in a database. Two distinct levels of filing have also been defined, a more synthetic one (minimum fiche) and a more extensive and detailed one (full fiche).
An initial outcome of the register project was published in the volume edited by Dennis Sharp e Catherine Cook, *The Modern Movement in Architecture / Selections from MOMO Registers* (Brasilia, 2000), which includes 800 buildings from 35 countries. Since 2003, the Docomomo International Register has been implemented systematically with fiches on buildings belonging to specific types, such as "machine, factory and modern architecture" in 2008[49]. The European register includes a number of industrial buildings, including masterpiece such as the Werkbund-Musterfabrik (Gropius, 1914), the AEG-Turbinenfabrik (Behrens, 1909), the Lingotto Factory (Mattè-Trucco, 1915-1922), the Usine Dodane (Perret, 1939-1943), the Fagus Factory (Gropius, 1911-1925), the Zollverein complex, and several notable buildings from the '50s and '60s, such as the ENSIDESA complex, the Olivetti Industrial Complexes (Cosenza, Figini), the Solimene Ceramics Factory (Soleri, 1953), the Cummins Factory (Roche, 1963), The Horizon Building (Stirling, 1968), the Seat factory (Brueckner, 1953). Additionally, several national chapters of Docomomo have recently

[47] www.formsandstructures.polimi.it.

[48] The international association was founded in 1990, agreeing on the statutory task of drafting of an international register of the most significant architecture of the modern movement so that it can be preserved and documented.

[49] www.archi.fr/UIA/.

selected hundreds of works of industrial architecture, such as the 160 buildings and sites included in the catalogue *Arquitectura de la industria, 1925-1965. Registro Docomomo Ibérico* (Docomomo, 2005).

At a national level, in 1994 Docomomo Italia began the cataloguing, with the first 80 fiches and a series of poster exhibited at the international conferences[50]. In 2014, Docomomo Italy made a selection of the 100 most important works which represent twentieth century Italian architecture: the catalogue of the works selected for Italy, with their fiches, including those entered in the International Register[51]. Among the selected buildings, the register includes also several office buildings and factories from the middle-twentieth century, such as the Pescia Market (Brizzi, Gori, Gori, Ricci, Savioli, 1951), the Olivetti factory in Pozzuoli (Cosenza, 1955), the building in Sant'Andrea factory (D'Olivo, 1958), Zanussi Offices (Valle, 1961) and the Burgo factory (Nervi and Covre, 1964).

[50] The Catalogue of the works was published in 1994 and various Register posters were issued in 2003, 2006, 2007, and 2008.

[51] The Docomomo Italia Register is available online at www.docomomoitalia.it/register/; the international selection is available in a virtual exhibition at www.exhibition.docomomo.com.

Mapping and cataloguing concrete industrial buildings: methodology, sources and references

The selection of the relevant industrial buildings for the database has been carried out taking into account the approaches and the assessment criteria currently used at national and international level for the identification of significant works of modern and contemporary architecture; thus the criteria proposed by Docomomo for the works of the modern movement and by MiBACT for the cataloguing of the late twentieth century architecture have been considered.

More specifically, these principles for selection are usually based upon a series of historical-critical criteria which take into account bibliographical references as well as consideration about significance and values linked to the contexts: if the work is published in more than two studies on regional or Italian architecture; if the work is published in more than two international journals; if the work plays an original or significant role in regional developments in relation to international research and debate; if the building has a significant role in the typological evolution, through innovative or experimental constructive solutions; if the building was designed by a prominent figure of regional, national or international architecture; if the building shows particular qualitative value within the urban context.

However, having in mind such criteria, the study was oriented to include in the catalogue a substantial number of buildings, beside specific bibliographical parameters, in order to complete a mapping as accurate as possible, which could also highlight the presence of less-known valuable buildings. The survey has therefore originated from a systematic examination of Italian publications related to modern and contemporary industrial heritage, the activity of architects and construction companies, and the advancements in concrete technology and prefabricated construction, during the years considered. In detail, the literature review has involved:

- books from the '60s on the theme of industrial architecture, which also include case-study project of those years (Guarneri and Morasso, 1958; Forti, 1964; Aloi, 1966; Cavallotti, 1969; Raja, 1983);
- handbooks and catalogues from the '60s and '70s about industrialised and prefabricated construction, which also present several building case-studies (Pacenti, 1965; Koncz, 1969);
- architectural and technical journals from the '60s and '70s, especially articles which present relevant projects of industrial buildings (*Domus, Casabella, L'architettura: cronache e storia, Il giornale dei costruttori, L'industria Italiana del Cemento, La prefabbricazione, Prefabbricare, Modulo*);
- recent relevant literature on post-war Italian architecture (Poretti, 2009; Desideri *et al.*, 2013; Melograni, 2015), industrial architecture and related topics (Castronovo and Greco, 1993; Ronchetta and Trisciuoglio, 2008; Parisi, 2011; Ramello, 2013; Vettori, 2013) and concrete in architecture (Andriani, 2006; Andriani, 2008; Iori and Marzo Magno, 2011; Andriani, 2011; Andriani, 2012; Faresin, 2012; Andriani, 2015), which often examines notable industrial buildings;

- monographs about Italian architects who worked in the field of industrial and industrialised building;
- national and local guides on modern and contemporary architecture (Polano and Mulazzani, 1996; Biraghi *et al.*, 2013);
- archives of architectural firms and construction companies;
- online database and catalogues on modern and contemporary architecture.
-

The records included are organised upon the basis of the *minimum fiche* (as defined for the Docomomo register), which also allows future implementations. The forms for documenting modern buildings and sites, urban developments, gardens and landscapes are proposed by Docomomo in two formats: the *minimum fiche*, which is the basis of the Register database and summarizes the essential data in a brief form, and the *full fiche*, which is meant for scientific research and documentation, as well as for raising awareness of modern architecture at an international level. Both the fiches cover generic and specific topics about the built heritage, including historical, technical and social aspects.

The Docomomo guidelines to complete the fiches for the international register (2003) also highlight some basic principles of the selection and documentation process (table 1-1). The fiche is in fact designed to ensure uniformity in recording but also to provide scientific record and accurate data. Moreover, some sections focus on the assessment of the value and significance of the building/site, in accordance with the aim of the register.

The *Identity of the building* (1) section allows the identification and location of the building/site, also using addresses and map references, and also provide information on its status of protection. The *History* (2) section highlights the design and building process, recording chronology and development of the site, relevant persons and organisations involved in the project and events associated with the building, and the current use and condition of the site. The *Description* (3) section focuses on the main characteristics of the building/site, including the physical and architectural features of the building (design, architectural details, materiality, and structural systems), the process and method of constructing the building/site, the context, such as the surrounding project site. The *Evaluation* (4) section is to provide an overall assessment of the significance of the building in the context of the Modern Movement. Each sub-section considers specific aspects and intrinsic values of the building/site, stressing its innovatory aspects: the technical evaluation is meant to assess the building/site according to its use of new materials and innovative techniques, including building materials and finishes, building methods, and structural systems; the social evaluation considers the intended program of the building/site as regards social and economic issues present at the time of design; the cultural & aesthetic evaluation focuses on the formal strategies of the designer and the formal qualities of the building; the historical evaluation considers the building/site according to its position in architectural history and how it was received; finally, the general assessment is a brief concluding statement of significance.

Minimum Documentation Fiche 2003	Guidelines documentation fiche 2003
	composed by national/regional working party of:
0. Picture of building/site	
	depicted item:
	source:
	date:
1. Identity of building/ group of buildings/ urban scheme/landscape/garden	
	1.1 current name of building
	1.2 variant or former name
	1.3 number & name of street
	1.4 town
	1.5 province/state
	1.6 zip code
	1.7 country
	1.8 national grid reference
	1.9 classification/typology
	1.10 protection status & date
2. History of building	
	2.1 original brief/purpose
	2.2 dates: commission/completion
	2.3 architectural and other designers
	2.4 others associated with building
	2.5 significant alterations with dates
	2.6 current use
	2.7 current condition
3. Description	
	3.1 general description
	3.2 construction
	3.3 context
4. Evaluation	
	4.1 technical
	4.2 social
	4.3 cultural & aesthetic
	4.4 historical
	4.5 general assessment
5. Documentation	
	5.1 principal references
	5.2 visual material attached
	5.3 rapporteur/date
6. Fiche report examination by ISC/R	name of examining ISC member:
	date of examination:
	approval:
	working party/ref. n°:
	NAI ref. n°:
	comments:

Table 1-1: scheme of the minimum documentation fiche (Docomomo, 2003)

The guidelines for the Docomomo Register also propose a classification of modern building typologies, which includes 18 categories (table 2-1). The buildings considered in the present study mainly belong to the category Industrial (IND) and sometimes to the Public Services category (PBS), such as heating, electricity or water supply, or Commercial (COM), such as offices linked to industrial activities.

Abbreviation	Typology	Examples
ADM	Administration	Government, civic, and public buildings, Professional institutions
COM	Commercial	Banks, Markets, Offices, Restaurants, Retail, Service premises, Storage buildings
DEF	Defense	Fortifications, Military Installations
EDC	Education	Libraries, archives, record offices, Research establishments, Schools, Universities and colleges
FAF	Farming, Fishing	Farming, Fishing, Forestry, Horticulture
FNR	Funerary	Cemeteries, graveyards, Funerary monuments, mausolea
HLT	Health	Hospitals, Health Centres
IND	industry	Building industries, Ceramics, Chemicals, Engineering, Extractive industries, Food and drink processing, Marine construction, Metal industries, Textiles, Wood-working industries
LAW	Law	Law courts, Penal institutions, Police buildings
LND	Landscape	Agricultural settlement, Botanic gardens, arboretums, Forestry, Land reclamation, National and regional parks
MON	Monuments	Public, commemorative monuments, Sculpture (free-standing)
PBS	Public Services	Baths, swimming pools, District heating, Electricity supply, Gas supply, Hydraulic power supply, Sanitary provision, Water supply, drainage, sewage disposal
REC	Recreation	Cinemas, Concert halls, Museum, art galleries, Pavilions, club houses, Public parks, gardens, Sports centres, gymnasia, Stadia, sports grounds, Theatres
REL	Religious	Cathedrals, chapels, churches, mosques, synagogues, temples, other places of worship, Church halls, meeting houses, religious centres, Seminaries, Presbyteries, manses, Monasteries, convents, religious houses, Shrines, places of pilgrimage
RES	Residential	Castles, palaces, fortified houses, Communal housing, Country houses, mansions, large villas, Hotels, Inns, Small detached houses, cottages, tenements
TRC	Transport	Broadcasting, Bus services, Canals, Civil aviation, Post services, Railways, tram ways, Roads, paths, Shipping, Telecommunications
URB	Urbanisim	New towns and villages, Town extensions, Urban development, reconstruction
UNC	Unclassified	

Table 1-2: building classification for the Docomomo Register (2003)

1.2.2 The database and the website on concrete industrial architecture in Italy: organisation and visualisation of data

As industrial architecture in Italy has largely concentrated upon concrete construction techniques, especially through the evolution of prefabrication, the diffuse and fragmented industrial landscape of the country mainly consists of prefabricated industrial buildings from the '60s and '70s. Recognising that the identification of examples of emergent industrial architecture is, above and beyond any kind of intervention, a much-needed step towards ‘critical knowledge’, research into the issue has produced the catalogue of “Concrete industrial architecture in Italy 1950-1980”, which lists notable buildings constructed using both cast-in-place and pre-cast concrete methods.

The data on industrial buildings has been collected and organised in a specifically-designed database. The database provides an overview of the study of Italian industrial architecture and prefabricated industrial building and also highlights some of those specific aspects - such as historical, technical and cultural-aesthetic features - which characterise the research.

The database, originally intended as a tool for managing and updating the large amount of data (and pictures), is also usable for future implementations, being open to the addition of both records (more buildings) and fields (category of information and specific research topics). It is an approach which therefore promote an organic evaluation of the topic, favouring the understanding of the values and characteristics of the selected buildings in the context.

The content is organised in the database[52] according to two basic tables of data:

- the complete catalogue of works: industrial buildings made with concrete construction systems in the period 1950-1960 in Italy;
- the catalogue of construction companies and precast concrete industries active in Italy between 1950 and 1980.

The visualisation and review of data is organised through a set of views/formats:

- a list-view for the full list of the buildings included in the database on concrete industrial architecture in Italy between 1950 and 1980; a list-view for the short list of case-studies - building made with the use of precast concrete panels;
- a list-view for the catalogue of precast concrete companies;
- a single view consisting in a synthetic and extended fiche including information on each building case-study, based on the *Docomomo fiche* scheme and instructions.

Thus each single view - format - is designed to display different fields of information, depending on the level of detail of the study.

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[52] The database was designed and managed through the software FileMaker (©1984-2013 FileMaker, Inc.).

The list-views of the catalogue - complete list and case-studies list - show: the name of the building, the authors, the construction company or manufacturer, the dates of construction, the address (street, city, state), the geographical coordinates, the link to other online catalogues, the bibliographical references, and an identifying image of the building (F. 1-79).

The list-view for the list of companies provides information on the name of the company, the city, the years in business, the website, the sign or logo.

The synthetic fiche displays: the name of the building, the designer, the construction company or manufacturer, the dates of construction, the address (street, city, state), the geographical coordinates, the type of building, the current use and condition of the building, a brief description, the link to other online catalogues, the bibliography and an image gallery (F. 1-80).

The extended fiche shows all the fields of the *Docomomo minimum fiche* (paragraph 1.2.1). The functions available in the database allow the sorting and classification of the records (buildings) according to their names, dates of construction, authors, location, etc., while it is also possible to link between the lists and single-views. In detail, the operations available are:

- sort or search buildings by: name, author, date, province, or external references;
- display of the location of the building on a external map;
- display of the single-view (when available, synthetic or extended) of buildings;
- open the fiche dedicated to the building in other online catalogues;
- link between list of buildings and list of companies.

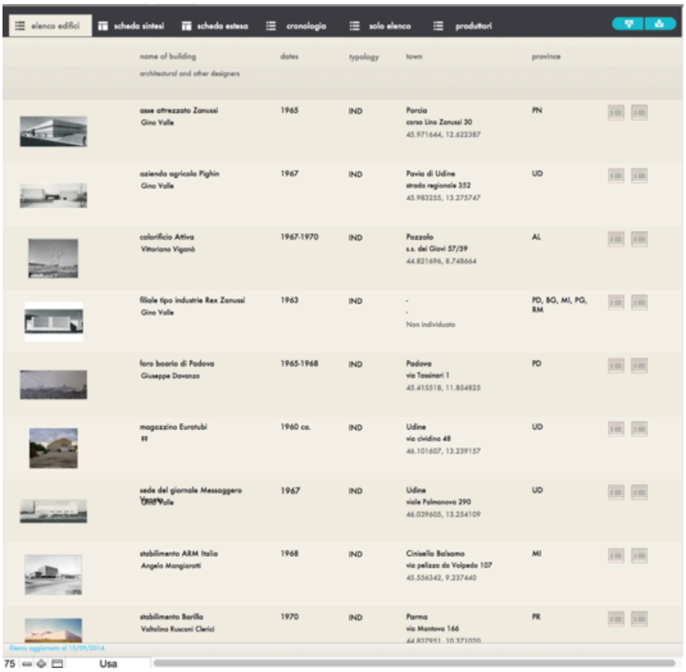
The database has been translated to a website[53], *CIA - Concrete industrial architecture in Italy 1950-1980 | AIC Architettura industriale in Calcestruzzo in Italia 1950-1980, un database per la conoscenza | un approfondimento sui prefabbricati,* in which the basic structure and the contents have been maintained, while the graphic style and visualisation formats have been partly redesigned (F. 1-81, F. 1-82) in order to improve usability, accessibility and portability.

The data have been imported and re-organised in an online database, which duplicates the original structure of the database. The website is thus organised in:

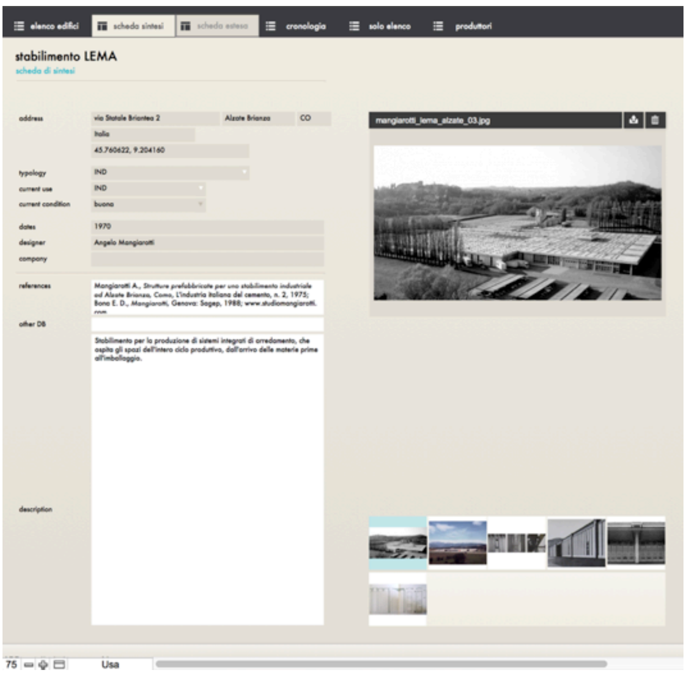
- a home page in full screen with main menu; and webpage about the research project and credits;
- a web page with the list of buildings (120), linked to the single-view pages, which includes an interactive map and a set of filters for sorting the building according to their name/authors/dates/location or selecting the case-studies;
- a series of single-view pages to show detailed information on case-study buildings (16/120), according to the scheme of the *Docomomo fiche*;
- a web page with the list of companies (about 100).

[53] The website is accessible online at architettura-industriale-calcestruzzo-italia.uniud.it/; the website will be published in open-access, together with the thesis, in April 2017.

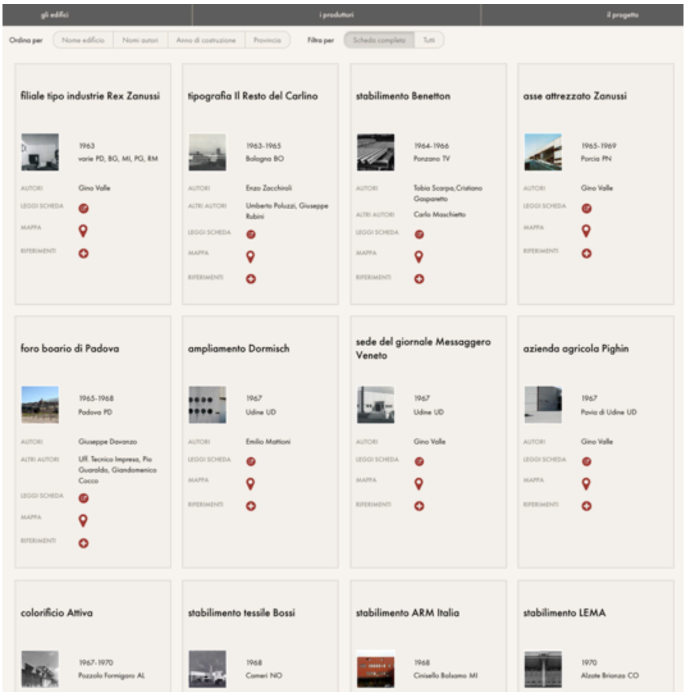
The referee can access the website by using the password: referee_2016



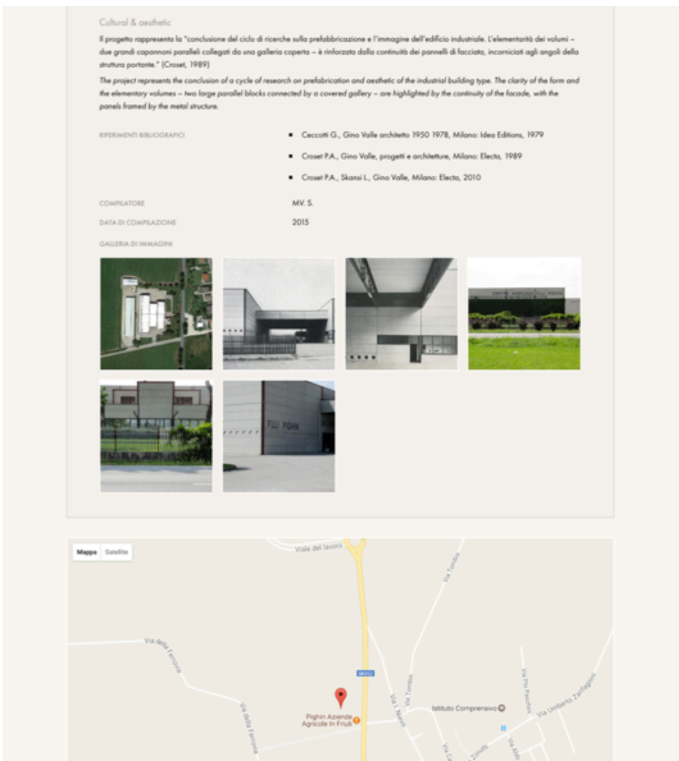
F. 1-79: list-view format in the database Concrete industrial architecture in Italy 1950 1980 (author, 2016)



F. 1-80: minimum fiche format in the database Concrete industrial architecture in Italy 1950 1980 (author, 2016)



F. 1-81: list-view format in the website Concrete industrial architecture in Italy 1950 1980 (author, 2016)



F. 1-82: single-view format in the website Concrete industrial in Italy 1950 1980 (author, 2016)

1.2.3 The industrial sector of concrete prefabrication in Italy

From the beginning of prefabrication, the advancement in precast concrete technology was also driven by the companies operating in this specialised industrial sector and which, from the '50s, in response to the growing market demand, became committed to the field. The collaboration between clients, designers and companies often led to relevant patents and the definition of specific building components or complete building types.

In Italy, however, the productive sector of precast concrete developed without effective coordination and homogeneity, due to the absence of a building industrialisation programme and the lack of modular planning, unification and specific regulation (Gregotti, 1986), and indeed was characterized by great differentiation in production. Furthermore, this very fragmented industrial sector tended to adapt to market demand, consisting in many small projects rather than significant programmes, so that a large-scale building industry never developed (Gregotti, 1986).
In the '70s, the Italian market situation was described by technical publications as mainly related to the industrial building construction, as almost 70% of the overall production of concrete was directed towards the industrial sector. This output was broken up in a very discontinuous way throughout the country, with the highest concentration in northern Italy (figures F. 1-83). The data, reflecting the industrial growth gap between the North and the South of the country, showed a remarkable number of companies in Lombardia, Emilia Romagna and Veneto, with sometimes more than a hundred manufacturers in the same 100 km area (Biondo and Rognoni, 1976g). This evidence also highlighted the prevalence of small and medium-sized companies scattered around the area which had specialised in several types of products. The lack of modular planning and of regulation standards in the Italian context exacerbated this differentiation.
The industrial prefabrication market grew very quickly between the '60s and the '70s, due to the heavy demand caused by the cycle of economic growth. This boom was uninterrupted until the late '70s, and the sector initially appeared to not be affected by the economic crisis of 1973-1974 (Biondo and Rognoni, 1976g). However, the recession also eventually struck the prefabrication market and the competition increased: after a general price reduction and the disappearance of lower quality products, many ‘minor’ firms and companies closed, while others directed their efforts to the civil sector.

Since the '50s, the Italian sector of industrialised and prefabricated concrete construction has been represented by the association *ASSOBETON - Associazione*

Nazionale Industrie Manufatti Cementizi[54]. The participating companies, given the variety of production technologies and markets, are divided into eleven sections according to their products, such as prefabricated structures. According to the data from the association, the companies producing precast concrete panels were 37 in 2014 (35 in 2016), while a wide-ranging survey carried out in 2015 reports 51 active companies in Italy.

The comparison of data from the last decade makes clear the scale of the crisis in the sector of prefabricated structures which has led to the gradual disappearance of many of these companies and is ascribable to several main reasons. On the one hand, the crisis in the industrial sector caused the abandonment or underutilisation of many industrial sites, implying a sharp decline in demand for prefabricated industrial buildings, which for a long time was the most important market for these companies. Secondly, the general crisis of the construction industry has severely affected these business, which for the specificity of their products and processes were, as has was the case with other construction companies, unable to convert for other sectors - public and residential.

Today, as in the past, despite a noticeably reduced presence, the localisation of precast concrete companies shows substantial differences across the country, with a high concentration in the northern Regions (Lombardia, Emilia Romagna and Veneto) and only a few companies operating in the South (F. 1-84).
The synthetic survey on Italian construction companies and factories of precast concrete elements resulted in a list of companies (Table 1-3) included in the database, which were active in the period between 1950 and 1980. Some companies stand out for their long-lasting activity or their widespread influence (F. 1-85), while others stand out for the relevance and quality of their few works or for the validity of their collaborations with notable figures.
Information on the industries included the type of products marketed, showing that most of the companies which specialised in the industrial building sector produce complete prefabricated systems, including structural elements (beams, pillars, slabs) and cladding elements (panels and special components).

In this context, the problem of the archives of the construction companies also arises and, as pointed out by other studies, it has often proved difficult to persuade the construction industry to participate in archival research. Additionally, construction companies of the past often demonstrated a lack of awareness of archives and archival organisation, so that the documents cannot be easily accessed.

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[54] The history of the association is presented in (Assobeton, 2006) www.assobeton.it. ASSOBETON participates in Confindustria, Federbeton, Federcostruzioni and, internationally, in BIBM - European Federation for Precast Concrete www.bibm.eu.

It must be noted that construction companies, as well as architectural firms, especially since the '50s, have made a major contribution to the economy and the technological advancement of the country. Nevertheless their archives are not generally well-known or understood and, besides their value as a part of the country's archival heritage, historical records are important sources for a range of academics and researchers.
The topic has become increasingly pertinent in the last years, given that a number of renowned companies of the construction sector have closed, leaving their archives to an uncertain or unknown fate.
In this sense, in recent years many initiatives have been dedicated to industrial archives[55] besides the official archival record system[56]. However, both the national archival system and the collections resulting from these initiatives include, for the moment, only a few records regarding construction companies and other business of the construction sector (such as precast concrete companies). Hopefully, by learning from the experience of other countries[57], a systematic survey of the field in Italy too could lead to significant outcomes.

[55] Such as the Online center for industrial culture *STORIAINDUSTRIA - Centro Online Storia e Cultura dell'Industria* (www.storiaindustria.it), the Italian association of company museums and archives *MUSEIMPRESA - Associazione italiana dei musei e degli archivi d'impresa* (www.museimpresa.com).

[56] The Italian National archival system *SAN - Sistema Archivistico Nazionale* (SAN) since 2009 includes a section on business companies (www.imprese.san.beniculturali.it/web/imprese/).

[57] A comprehensive survey on construction companies and architectural firm archives in England and Wales was conducted between 2011 and 2013 in partnership between the Business Archives Council and The National Archives, focussing on collections which were not deposited in archival repositories, as presented in the report *Architecture, building and construction records survey 2011-13* (National, 2013).

COMPANY [CONSTRUCTION COMPANY OR PRECAST CONCRETE PRODUCER]	PROV.	CONSTI TUTION DATE	CURRENT ACTIVITY	PRODUCTS
PREFABBRICATI QUARANTA	CE	1900*	operating	complete system
IMPRESA ING. MORGANTI	MI	1901	operating	on-site prefabricated components
BORTOLASO PREFABBRICATI	VR	1903		
PREFABBRICATI PASOTTI	BS	1908	operating	complete systems
VELO S.P.A.	PD	1943	operating	vertical structures beams and roof structures cladding panels complete systems
NICO VELO S.P.A.	PD	1943	operating	vertical structures beams and roof structures cladding panels accessory components
BARACLIT S.P.A.	AR	1946	operating	complete systems
VALDADIGE S.p.A..	VR	1950	closed	
SIPRE PREFABBRICATI	UD	1950	closed	cladding panels
PREFABBRICATI PIZZAROTTI	PR	1950 (1910)	operating	vertical structures beams and roof structures cladding panels
ASTORI	MI	1950 *	incorporated 1991	vertical structures beams and roof structures cladding panels complete systems
PIZZUTI PREFABBRICATI S.R.L.	KR	1950 *	operating	beams and roof structures cladding panels complete systems
GENERALE PREFABBRICATI S.P.A.	PG	1950 *	operating	cladding panels
GRANDI LAVORI	RM	1950 *	operating	vertical structures beams and roof structures cladding panels
PREFABBRICATI ZANON	PD	1953	operating	vertical structures beams and roof structures cladding panels accessory components complete systems
PREFABBRICATI CAMUNA S.R.L.	BS	1956	operating	vertical structures beams and roof structures cladding panels complete systems
TRUZZI S.P.A. CON UNICO SOCIO	MN	1956	operating	vertical structures beams and roof structures cladding panels accessory components
PRECEM	VR	1956	closed	
PREBI PREFABBRICATI BIGONTINA	MI	1957		
BETON FRIULI S.R.L. (S.P.A.)	UD	1960		
S.I.L.C.A.	TV	1960		beams and roof structures accessory components

COMPANY [CONSTRUCTION COMPANY OR PRECAST CONCRETE PRODUCER]	PROV.	CONSTI TUTION DATE	CURRENT ACTIVITY	PRODUCTS
S.P.E.S.	TV	1960		beams and roof structures
S.P.A.V	UD	1960	closed	vertical structures beams and roof structures cladding panels
SAR COSTRUZIONI PREFABBRICATE S.R.L.	MN	1960	operating	beams and roof structures cladding panels
SICEP S.P.A.	CT	1960 *	operating	cladding panels complete systems
ZECCA PREFABBRICATI S.P.A.	SO	1960 *	operating	vertical structures beams and roof structures cladding panels
STYL-COMP S.P.A.	BG	1960 *	operating	cladding panels accessory components
FACEP	MI	1960 *	closed	complete systems vertical structures beams and roof structures cladding panels
EMA	MI	1960 *	-	
BONOMI E VECCHI	MI	1960 *	closed	
ISOCELL	BG	1960 *	closed	
CEVI	UD	1962		
MC-MANINI PREFABBRICATI S.p.A.	LO	1962	operating	cladding panels
MANINI PREFABBRICATI S.p.A.	PG	1962	operating	cladding panels accessory components complete systems
PREFABBRICATI FORESI S.R.L.	MC	1962	operating	vertical structures cladding panels
STERCHELE S.p.A.	VI	1962	operating	cladding panels accessory components
ALTAN PREFABBRICATI S.p.A.	PN	1963	closed	cladding panels complete systems foundations beams and roof structures vertical structures
S.I.P.E.	VI	1963	operating	vertical structures beams and roof structures cladding panels complete systems
EDILCEMENTO S.p.A.	PG	1963	operating	
DMP DALLA MORA	VE	1964	operating	
CSP PREFABBRICATI S.p.A.	BG	1965	operating	
CHIONS PREFABBRICATI	PN	1966	operating	
STAI PREFABBRICATI S.R.L.	MN	1966	closed	beams and roof structures complete systems
MORETTI PREFABBRICATI S.R.L.	BS	1967	operating	cladding panels complete systems
SITCO	VR	1969	operating	
MOZZO PREFABBRICATI S.R.L.	VR	1969	operating	cladding panels

COMPANY [CONSTRUCTION COMPANY OR PRECAST CONCRETE PRODUCER]	PROV.	CONSTI TUTION DATE	CURRENT ACTIVITY	PRODUCTS
MC PREFABBRICATI S.p.A.	VA	1970	operating	cladding panels complete systems
FARBOX PREFABBRICATI	PN	1970 *	closed	complete systems
MONOPANEL	PN	1970 *	incorporated	beams and roof structures cladding panels accessory components
FERRARINI S.R.L.	VR	1970 *	operating	beams and roof structures
IMPRESA TRE COLLI S.p.A.	AL	1970 *	operating	accessory components
MARTINI PREFABBRICATI S.p.A.	MN	1970 *	operating	vertical structures cladding panels
PREFABBRICATI PERUZZI	Si	1970 *	incorporated 1988 (RDB)	vertical structures beams and roof structures cladding panels
FRIULANA IMPRESA MANUFATTI EDILI (FIME)	PN	1970 *	operating	small precast concrete accessory elements
SACIE	MI	1970 *	closed	
ANTONIO BASSO S.p.A.	TV	1972	operating	vertical structures beams and roof structures cladding panels complete systems
LARCO	MI	1972	incorporated	cladding panels
DAL CIN PREFABBRICATI	PN	1973	operating	vertical structures beams and roof structures cladding panels
E.M.E. URSELLA	UD	1976	operating	cladding panels accessory components complete systems
COOPSETTE SOC. COOP.	RE	1977	operating	vertical structures beams and roof structures cladding panels
ZANETTE PREFABBRICATI	PN	1980 *	operating	vertical structures beams and roof structures cladding panels complete systems
SEIEFFE PREFABBRICATI S.p.A.	BN	1980 *	operating	vertical structures cladding panels complete systems
CONCRETE CAPANNONI PREFABBRICATI	PN	1991	operating	vertical structures beams and roof structures cladding panels complete systems
EDIMO PREFABBRICATI S.R.L.	AQ	2006	operating	
BONOMI A.	TN		incorporated	complete systems
CIFA	MI		operating	
COLTRI PREFABBRICATI	VR			
F.LLI CLINAZ SNC	UD			accessory components
FRIULANA CEMENTI				

COMPANY [CONSTRUCTION COMPANY OR PRECAST CONCRETE PRODUCER]	PROV.	CONSTI TUTION DATE	CURRENT ACTIVITY	PRODUCTS
IBC INDUSTRIAL BUILDING COMPANY S.p.A..	VR		operating	vertical structures beams and roof structures cladding panels accessory components complete systems foundations
IMPRESA EDIL - CISA S.P.A.	UD		closed	
POZZOBON PREFABBRICATI PRECOMPRESSI	TV	1970	operating	vertical structures beams and roof structures cladding panels complete systems
BATTILANA PREFABBRICATI	VI		operating	vertical structures beams and roof structures cladding panels complete systems
PREFABBRICATI MANGIAROTTI	PN		operating	
SALICE CENTRIFUGATI	TV			
SICMEL S.P.A.	BL			
EUROBETON			operating	
PRE SYSTEM S.P.A.	UD		operating	vertical structures beams and roof structures cladding panels complete systems
PRECAST S.P.A.	PN			
GEOCAP S.R.L.	CN		operating	vertical structures beams and roof structures cladding panels accessory components complete systems
NUOVA TESI SYSTEM S.R.L.	TV		operating	
AREA PREFABBRICATI S.p.A.	RE		operating	beams and roof structures cladding panels
PADANA PANNELLI S.P.A.- VD. TRUZZI	MN		operating	
ZANETTI S.R.L.	VR		operating	
M.G. PREFABBRICATI S.R.L.	CR		operating	cladding panels
ESAG PREFABBRICATI				complete systems
VIANINI				
SOCIETÀ ITALIANA PREFABBRICATI S.p.A.	RM			vertical structures beams and roof structures cladding panels

Table 1-3: list of precast concrete companies in Italy included in the database Concrete Industrial Architecture in Italy, sorted by the constitution dates.

The comprehensive list of companies involved in the industrial building sector, although not exhaustive, illustrates well the past and present scenario of concrete prefabrication for industrial constructions in the country.
Furthermore, in this context, the case of some specific Italian companies which were active in the regional area favours a comparison between the different approaches and results in the field of concrete prefabricated construction. While ALTAN Prefabbricati S.p.A. grew from the '60s, specialising in concrete prefabrication for industrial buildings and gaining a prominent role in the Italian context, from the ‘50s EME Ursella S.p.A. focused its activity on precast concrete for the civil sector and especially prefabricated modular houses; differently again, the Zanussi building branch started its business in the '60 as a construction company for industrial plants but later redirected its efforts to experimental prefabricated houses.

The history of the ALTAN Prefabbricati S.p.A. company began in 1963, the year of foundation of the E.P.I.C.A. S.r.l. company, which consolidated the ideas, insights and studies into precast reinforced concrete previously applied by the surveyors R. Altan and E. Termini. The company was one among the first in northern Italy to begin in the industrialised building sector with its own plant for the production of precast concrete components. In 1966, the company started the production of precast prestressed concrete in two additional production facilities. The technical, organizational and managerial skills and the special machines owned by the company led to a significant growth and important commissions in the industrial and civil sector[58]. The phase of expansion continued up to 1992, while the crisis of the sector later led the company to bankruptcy and liquidation in 2014[59].
The company evolved from a surveyor’s office into one of the most important firms in the country following the emerging technologies and the market trends of the period. The early elements produced were the pillars and the arches for vaulted roofs; the turning point was the introduction of prestressed concrete, a technology which totally changed the industrial building type, allowing to reach spans from 10 meters to 20 meters (e.g. the Jesse furniture factory in Brugnera, Pordenone, 300 m x 100 m).
The production of these components actually started in the '60s, when the first mould to cast double-T slabs - the prestressed elements with standardised dimensions - was purchased from Germany (Munich). The length of the production line (100 m) led to the introduction of solutions to accelerate the curing of concrete (heat and vapour-curing) and ease the stripping (nylon layers), in order to obtain a finished component in 24 hours.

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[58] Information and documentation on ALTAN PREFABBRICATI S.p.A. are available on the company’s website www.altan.com.

[59] The archive of the company was not available for consultation as the company closed in 2014, thus the information here summarised and some informative material were kindly provided by a former employee, Saverio Martin, who worked in the technical office of the company since its foundation. The interview took place on 26th May 2015 in the headquarters of ALTAN Prefabbricati S.p.A.in Ramuscello (Pordenone).

Shortly afterwards, the company also started producing T-shaped beams, with spans of up to 30 meters with standardised dimensions of 250 cm in width and 25 cm, 42 cm, 45 cm or 76 cm in height.
The company was thus organised to provide a turnkey project through a complete service, including the production of precast concrete components (also the manufacturing of mould for special elements in the mechanical workshop), the transportation and assembly of buildings (with its own vehicles and cranes), and the structural and architectural design of building.
In the '70s and '80s, the company reached a the peak of activity, with around 150 employees and a technical office managed by 5 engineers, whose main task was to 'translate' into prefabricated components the projects developed by other firms.
The architectural research into prefabricated construction and components started with the collaboration with the architect Gino Valle (1923-2003), which also led to the construction of several industrial building (e.g. for the Zanussi Industries and Fantoni). One interesting aspect of this collaboration was the introduction of a module of 1.20 m instead of the submultiples of the module of 2.50 m, which was the standard for industrial constructions. For the design of residential, public and industrial building, the company collaborated with many other architects active in the area, such as Marcello D'Olivo, Giovanni Tenca Montini, Glauco Grasleri.
However, in that period, industrial building spread enormously and the company, like many others, adopted the standard construction for the industrial building type: a structural grid based on 20 m or 10 m module (sometimes 7.5 m) and a set of standardised building elements, including square-section pillars, L-shaped and T-shaped beams, double slope beams and double-T slabs. However, the catalogue of components included also V-shaped slabs, Y-shaped slabs, I-shaped beams, and special components such as *brise-soleil* and corner elements.
The cladding elements were usually precast concrete panels (2.50 m x 10 m) with prestressed rebar and steel mesh. Sometimes the panels produced by the company were combined with metal structures produced by other local industries (such is the case of the building designed by Valle). The horizontal solution was generally preferred due to the lesser costs for the integration of windows. The panels were solid, with thicknesses of 12 cm, 16 cm, 20 cm or 30 cm, and later with an insulation layer in high-density rock-wool or expanded clay. The surface finishing was generally standard, but panels with exposed aggregate were also produced.

In the course of the development of the present study and the research related to it, the brief experience of the Zanussi Industries in the building sector - with its building-branch <u>Zanussi Edilizia Industrializzata</u> (ZEI) later <u>Zanussi-Farsura</u> - resulted of particular interest.
Zanussi Industries were involved in the construction industry from the '50s, when Guido Zanussi, breaking away from the family company, began to work in the real estate field (i.e. in 1958 handles the construction and land transactions for the first plants) (Burello, 2010). In the '60s, in fact, a new branch of the Zanussi Industries was

in charge - as construction company - of the realisation of the Zanussi plants in Porcia and Vallenoncello (Valle, 1963, 1967, and 1969).

In the second half of the '70s, within a policy of corporate diversification of the Zanussi Group, a construction division was constituted, named Zanussi Industrialised Building (ZEI) and later Zanussi-Farsura (1977-1987). The main product of the company was the "industrialized habitat", i.e. a modular system for housing, consisting of prefabricated three-dimensional modules. It was of a prefabricated product with "high level of finishing", whose components were totally produced and assembled in the factory (including plaster, panelling, bathroom fixtures, wall units and system arrangement) while only the connection operations and painting were executed on-site.

The Zanussi-Farsura module was proposed in three types (a central module with 4 sides, a 5-sided head module, a module with bathroom or wall system). The overall dimensions were determined by the constraints for the transport (i.e. the container dimensions, and then 2.50 x 10.00 m); the structure of the module consisted in reinforced concrete walls, 10/12 cm thick if solid, or 5+3+7 cm thick with polyurethane insulation layer (Giuliani and Gerola, 1982).

The factory operated as a real industry and the modules were realised through six production lines, operating continuously: in the first part of each line of the r.c. wall elements were casted through customizable formworks, thanks to vapour curing which, combined with a high cement content, allows the stripping in about 3-4 hours; the product then continued across the various step of the production line to be finished.

Over a few years, the company changed location several times: the production activity was begun in a prefabricated shed of Zanussi in Comina, in Pordenone, and was then transferred to Spilimbergo (offices) and finally to the plant in Istrago near Spilimbergo.

From the early stages of the activity, several principal problems of the industrialized habitat system emerged, some in accordance with the many critical aspects of precast products developed in those years, others peculiar to the Zanussi-Farsura module, which together probably determined the limited success of the system and the short lifespan of the company[60].

However, some industrialised habitat Zanussi-Farsura habitats were built across the country: some complexes of semi-detached houses (two- or three-storey) in the Friuli Venezia Giulia region - e.g. Travesio, Sequals, Porcia, Vallenoncello, Martignacco - and some adapted versions for specific projects - e.g. IACP blocks with solar greenhouse in Pordenone and a military facility of five storeys in Monrupino (Pordenone).

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[60] Interview with Claudio Bertolo eng., ATER Trieste, technical employee from 1984 to 1986 at Zanussi Edilizia Industrializzata (date: 15th february 2016).

Interview with Giacomino Paolo Rizzi surveyor, Azienda Ospedaliera Universitaria di Udine, technical employee at Zanussi-Farsura from 1978 to 1979 (date: 16th february 2016).

Following the earthquake in Irpinia, in the '80s the company focused on the construction of dwellings in southern Italy (1500 units) and opened a plant in Caserta, dedicated to adaptation of existing modules and production of new ones. In the late '80s, the company was sold and incorporated by the Fasano group, established in Taranto, leaving the abandoned plant, however, with its storage of products, in Spilimbergo.

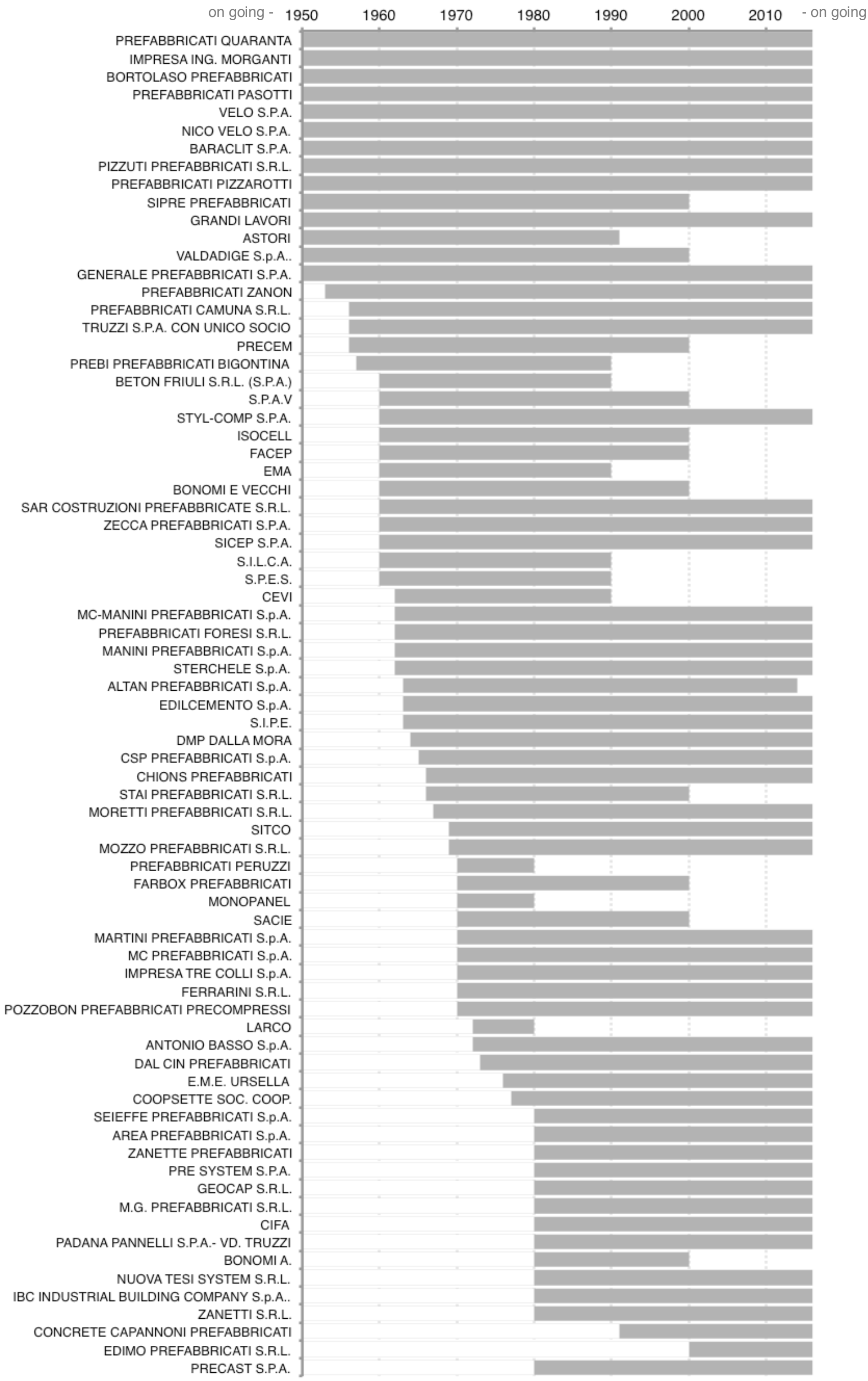
The E.M.E. URSELLA S.p.A. company, even though founded in 1976, began operating after World War II, ahead of the trend in prefabrication, producing factory-made concrete construction components, destined to grow over time, both in technology and dimensions. In the ‘50s, the company also started working with well-known architects, who were adopting concrete prefabrication for particular building elements otherwise difficult to build on-site. This partnership led to achievements such as the Villaggio del Fanciullo in Trieste (Marcello D'Olivo, 1950-1957) and the Commercial Centre in Lignano Pineta.
Prefabrication carried out in collaboration with D'Olivo is proudly remembered by the company as "harmonious and plastic"[61]. The collaboration in fact grew from the need to produce, in the first Ursella prefabrication workshop, original forms, exploiting the possibilities in the use of cement to create unique architectural elements - initially using plaster moulds - but in an economical way - reusing the moulds for producing pieces in series.
The first practical application of prefabricated concrete building elements was realised in the '60s with the production and assembly of the cladding panels of the Torre Zanier in Lignano Sabbiadoro. This system was then applied until the '70s in a wide range of buildings and especially in the production of residential villas. During the '60s, other precast concrete cladding systems were developed, starting from the blocks of the Lignano City complex and then used for other constructions in the Region.
Since the '70s, the company has focused on three-dimensional prefabrication, with the construction of prefabricated residential buildings based on the “Block-volume” module. The first use of the three-dimensional prefabricated units dates back to 1968, for the production of the watchtowers to be placed along the Tagliamento river. The limitations imposed by the high weight of the concrete structure and the lack of adequate insulation were, in fact, solved with the system “Block-volume” system, devised in 1975-76[62].

[61] Interview with Silvino Ursella at E.M.E. Ursella Spa, Buia - UD (date: 19th september 2014).

[62] History and other information on the company E.M.E. URSELLA S.p.A. are available online at www.emeursella.it; other interviews with Silvino Ursella are collected on the website of *CANTIRS Museo del patrimonio edile* of the Udine province (www.cantirs.it).

F. 1-83: maps of precast plants in Italy in the middle ‘70s (Biondo and Rognoni, 1976)

F. 1-84: map of precast concrete companies operating in Italy today, as included in the database Concrete industrial architecture in Italy 1950 1980 (author, 2016).



F. 1-85: precast concrete companies, sorted by the years of constitution and the duration of their activity - if closed or currently operating (author, 2016)

1.2.4 Concrete industrial architecture in Italy, 1950 - 1980: the catalogue

As industrial architecture in Italy has been largely based upon concrete construction techniques, from the '50s on, a large amount of building in the country was realised using both cast-in-place and pre-cast concrete methods. A number of these were designed by notable architects and engineers who saw in industrial architecture an opportunity for technical and formal experimentation. Well-known construction companies too were often involved in the field, even specialising in the sector.

Research into the topic results in the selection of about 150 relevant industrial buildings from the period, as summarised in the list below (table 1-4).
Despite some common features of these buildings, such as the large spaces and wide aisles, their former uses ranged from industrial to commercial and administration. The most numerous category is that of factories and industrial sites, which usually includes production facilities as well as offices and technical spaces; however, several energy plants were also built in more remote parts of the country, while commercial warehouses or distribution centres became fairly widespread in the outskirts of the major Italian cities.

The design of these factories involved notable architectural firms as well as prominent figures of structural engineering (Silvano Zorzi, Antonio Migliasso, Gino Covre, Aldo Favini), highlighting how industrial architecture had become a thriving field of application of architectural, structural and technological solutions. In several cases, additionally, it emerges that the projects (especially for the larger sites and factories) were often the result of the fruitful collaboration between the designers and the technical offices of the companies[63].
However, a more relevant perspective is introduced by the chronological interpretation of this building heritage (F. 1-86, F. 1-87, F. 1-88).
The '50s saw the construction of large complexes for well-known companies (Olivetti, Fiat, Pirelli) and building for the companies of the growing industrial sector.
Large concrete structures spread across the country, following the development of new structural elements or new forms, as in the case of parabolic structures, pursuing greater spans, wider spaces and better performances. Many other construction were also realised in the period, based around concrete skeleton structures in which the experimentation with reinforced concrete structural elements is still associated with more traditional building envelopes (bricks or blocks).

[63] To expand upon the 'company architecture' in Italy and the role of the technical offices see the recent studies by Marini and Santangelo (2014) and Vettori (2013)

The '60s saw the real spread of prefabricated concrete construction next to traditional, although innovative, concrete building methods. During these years a large amount of remarkable industrial construction was realised across the country, even including some masterpieces of modern architecture.
The prevalence of prefabricated building envelopes became evident mainly in the '70s, with the construction of notable factories, presented in the following paragraphs.
From a geographical point of view, as previously noted for construction companies, the presence of remarkable industrial buildings or sites is concentrated in the North of the country, with a prevalence in the more industrialised region such as Lombardy and Piedmont (F. 1-89, F. 1-90, F. 1-91).

NAME OF BUILDING	TOWN	PROV	DATES	ARCHITECTURAL AND OTHER DESIGNERS	OTHERS ASSOCIATED WITH BUILDING
Olivetti I.C.O. factory	Ivrea	TO	1934 - 1962	Gino Pollini, Luigi Figini	EduardoVittoria
Solari factory	Udine	UD	1948 - 1960	Giuseppe Valtolina,Carlo Rusconi Clerici	geom. Cozzi, Gino Valle
Emails factory	Filago	BG		Hans Fritz, Carlo Batello	P. Papini, A. Rognoni, Ufficio Tecnico Bayer
Magazzini del Sale	Tortona	AL	1950 - 1951	Pierluigi Nervi	
Centrale del Latte	Torino	TO	1950 - 1952	Luigi Buffa	
workshop in Porta Ticinese	Milano	MI	1951	Vico Magistretti	
Pirelli factory	Pozzuoli	NA	1951-1954	Luigi Cosenza	
Siciliano Cotton mill	Mondello	PA	1952	Pietro Ajroldi, Franco Gioè	
Manifattura Tabacchi	Bologna	BO	1952*	Bernard Zehrfuss, Marcel Breuer, Pier Luigi Nervi	
hydroelectric plant Basso Nera	Orte	VT	1953	Mario Pediconi, Acea Roma	
Olivetti workshop	San Bernardo, Ivrea	TO	1953	Nello Renacco	
Cementi Rossi testing workshop	Piacenza	PC	1953	Vico Magistretti	
factory in Brianza		MB	1954	Mario Asnago, Claudio Vender	
Olivetti industrial site	Pozzuoli	NA	1955	Luigi Cosenza	
San Pellegrino warehouse	Milano	MI	1955	Aldo Favini	

NAME OF BUILDING	TOWN	PROV	DATES	ARCHITECTURAL AND OTHER DESIGNERS	OTHERS ASSOCIATED WITH BUILDING
Sperlari factory	Cremona	CR	1955 - 1956	Gian Luigi Giordani e Ippolito Malaguzzi Valeri	Silvano Zorzi, Direzione Tecnica Sperlari e C. Pozzetti
dyeing plant	Rivoli	TO	1956	Aimaro Isola, Roberto Gabetti	
Olivetti Macchine Utensili production workshop	San Bernardo	TO	1956	Eduardo Vittoria	Gino Covre
Raffo factory	Pietrasanta	LU	1956	Leo Calini, Eugenio Montuori	Sergio Musmeci
Peroni brewery roof	Miano	NA	1956	Luigi Racheli	Ugo Viale
Ceramic factory	Palermo	PA	1956	Marco Zanuso	
Silvestri factory	Dormelletto	NO	1956	Aldo Favini	
industrial warehouse	Padova	PD	1957	Angelo Mangiarotti, Bruno Morassutti	Giovanni Morassutti
Olivetti Synthesis site	Massa	MS	1957	Piero Bottoni	Mario Pucci
Bombrini-Parodi-Delfino research centre	Colleferro	RM	1957	Riccardo Morandi	
Morando factory	Torino	TO	1957 - 1963	Francesco Dolza	Carlo Berta
Società Generale Semiconduttori factory	Agrate	MI	1958	Eduardo Vittoria	
fruit and vegetable market - loading platform	Firenze	FI	1958	Giorgio Morandi, Giulio Lensi Orlandi	
fruit and vegetable market - market platform	Firenze	FI	1958	Giulio Lensi Orlandi	
ICO factory	Ivrea	TO	1958	Luigi Figini, Gino Pollini, Goffredo Boschetti	Caponago Del Monte Pier Achille, Guiducci Roberto
Elit - Elettronica Italiana factory	Milano	MI	1958	Vittorio Borachia, Carlo Santi	
Monteshell petrochemical plant	Brindisi	BR	1958 - 1960	Ezio Sgrelli e Servizi Tecnici della Società	Corrago Jevorella, De Bernardis, Pagani
Cantoni Cotton mill	Legnano	MI	1958 - 1960	Vito Latis, Gustavo Latis	
Thermoelectical plant	Augusta	SR	1959	Giuseppe Samonà	
Ferrania factory	Roma	RM	1959	Julio Lafuente, Gaetano Rebecchini	calcoli costruttivi e dir. lavori: Francesco Tommasi
Morassutti warehouse	Padova	PD	1959	Bruno Morassutti, Angelo Mangiarotti	Aldo Favini
nuclear power plant	Sessa Aurunca	CE	1959 - 1962	Riccardo Morandi	Ufficio Tecnico Società elettronucleare nazionale
Lisio textile factory	Firenze	FI	1960	Renzo Falciani, Lido Puccini	G. Vanni, S. Cosco Mazzucca
Argenterie del Canavese factory	Loranzè d'Ivrea	TO	1960 - 1961	Carlo Viligiardi	Antonio Migliasso
Goti textile factory	Capalle	FI	1960 - 1961	Leonardo Ricci	Ernesto Trapani

NAME OF BUILDING	TOWN	PROV	DATES	ARCHITECTURAL AND OTHER DESIGNERS	OTHERS ASSOCIATED WITH BUILDING
factory and offices	Beinasco	TO	1960 - 1962	Corrado Levi	
Burgo paper factory	Mantova	MN	1960 - 1964	Pierluigi Nervi	Gino Covre
pover plant	San Floriano	BZ	1960 - 1964	Gigi Dalla Bona	
power plant	Naturno	BZ	1960 - 1964	Gigi Dalla Bona	
Ceramica Pozzi factory	Sparanise	CE	1960 - 1964	Luigi Figini, Gino Pollini	soc. Tekne, Roberto Guiducci, Francesco Misuraca, Silvano Zorzi, Gian Luca Papini, G. Borghi
industrial warehouse	Cesena	FC	1960 - 1966	Tihamer Koncz, Aldo Favini	
Everplast factory	Pomezia	RM	1961	Andrea Nonis	Adriano Bentivegna
FIMI factory	Rescaldina	MI	1961	Carlo Rusconi Clerici	Aldo Favini
Società italiana telecomunicazioni Siemens factory	Santa Maria Capua Vetere	CE	1961 - 1962	Antonio Antonelli, Manfredi Greco	Elio Giangreco, Giuseppe Giordano, Gino Parolini
Velca forniture factory	Legnano	MI	1961 - 1962	Vito Latis, Gustavo Latis	
Perugina factory	Perugia	PG	1961 - 1963	Carlo Rusconi Clerici	Angelo Alimo, Aldo Favini, Uff. Tecnico Sogene, Gustavo Hosel, Antonio Antonelli, Pietro Porcinai
Vittorio Bonacina forniture factory	Lurago D'erba	CO	1961 - 1963	Lorenzo Forges Davanzati, Piero Ranzani	Borgarello Pellegrini
storage and electrical substation for the subway	Sesto S. Giovanni	MI	1961 - 1964	BBPR	Silvano Zorzi, G. F. Bertolini, P. Maffioletti, L. Paiosa
exhibition halls in Bologna	Bologna	BO	1961 - 1967	Leonardo Benevolo	Tommaso Giura Longo, Carlo Melograni
Marxer research centre and factory	Loranzè d'Ivrea	TO	1962	Alberto Galardi	Antonio Migliasso
Rinascente warehouses	Roma	RM	1962	Aldo Molteni, W. J.Silberkuhl	
SIAG factory and services	Marcianise	CE	1962	Angelo Mangiarotti	Aldo Favini
Splūgen Brau warehouse	Mestre	VE	1962	Angelo Mangiarotti	Aldo Favini
Ranco Motori factory	Olgiate Comasco	CO	1962	Aurelio Moro, Mario Moro, Guido Gai	Giorgio Moro, B. Pellegrini
Lancia dealership	Roma	RM	1962	Eugenio Jaccod, Aldo Mascagna, Vito Camiz	
Parkel textile factory	Zola Predosa	BO	1962	Ferdinando Forlay	Studio Tecnico Ingegneri Gandolfi, Menarini, Morselli

NAME OF BUILDING	TOWN	PROV	DATES	ARCHITECTURAL AND OTHER DESIGNERS	OTHERS ASSOCIATED WITH BUILDING
Arianna textile factory	Masazza	BI	1962	Giovanni Corona, Giancarlo Delsignore	
Bristot coffee roasting plant	Belluno	BL	1962	Vincenzo Barcelloni Corte	Renato Bucchi, Piero Cosmai
Poretti brewery	Mestre	VE	1962	Angelo Mangiarotti	Aldo Favini
Sipre precast plant	Tavagnacco	UD	1962 - 1963	Gino Valle	
R.T.M. research centre	Vico Canavese	TO	1962 - 1964	Franco Papa	Nello Renacco, Ufficio Tecnico Olivetti Ivrea
Rex Zanussi model warehouses	various locations	PD, BG, MI, PG, RM	1963	Gino Valle	
Lombardini - Italiana Motori factory	Reggio Emilia	RE	1963	Cooperativa Architetti e Ingegneri di Reggio Emilia	
Aperol factory	Padova	PD	1963	Bruno Morassutti	Aldo Favini
Greco lighting factory	Milano	MI	1963 - 1964	Cesare Seregni e Ir. Lieuwe Op'T Land	Bagio, Bonis, Besana
Ma.Te.Si. textile factory	Roccella	PA	1963 - 1964	Fabio Mello	Giuseppe Belgiorno
Il Resto del Carlino printing factory	Bologna	BO	1963 - 1965	Enzo Zacchiroli	Umberto Poluzzi,Giuseppe Rubini
OM workshop	San Lazzaro di Savena	BO	1963 - 1967	Glauco Gresleri	Studio Tecnico Gandolfi-Menarini-Morselli, E. Baratelli, E. Stucki, H. Hofacker, M.Ceccatelli
nuclear power plant of Garigliano	Garigliano	CE	1964	Umberto Belelli, Raffaello De Felice, Riccardo Morandi	
Sib-Cocacola bottling plant	Firenze	FI	1964	Vico Magisretti	Gigi Mazza
Chinaglia factory	Veneggia	BL	1964	Vincenzo Barcelloni Corte, Adriano Alpago-Novello, Cesare Casati, Enzo Hybsc	G. De Prà
Benetton factory	Ponzano	TV	1964 - 1966	Tobia Scarpa, Cristiano Gasparetto	Maschietto Carlo, Sipre
Zanussi works canteen and offices	Porcia	PN	1965	Gino Valle	
prefabricated dome	Casaccia, Frascati	RM	1965	Carlo Cestelli Guidi, Antonino Giuffrè	
prefabricated industrial building	Padova	PD	1965	Enzo Bandelloni	
Alfa Romeo - clothing and assembly building	Arese	MI	1965	Giancarlo Giuliani	
Necchi factory	Pavia	PV	1965	Marco Zanuso, Pietro Crescini	Egone Cegnar, Raffaele Fidenza
wood factory	Genova	GE	1965	Renzo Piano	

NAME OF BUILDING	TOWN	PROV	DATES	ARCHITECTURAL AND OTHER DESIGNERS	OTHERS ASSOCIATED WITH BUILDING
Franchi factory	Borgosesia	NO	1965	Aldo Favini	
Cattle market	Padova	PD	1965 - 1968	Giuseppe Davanzo	Uff. Tecnico Impresa, Pio Guaraldo, Giandomenico Cocco
ELMAG factory	Monza	MB	1966	Angelo Mangiarotti	Alessandro Striscia Fioretti
Pepsi Cola factory	Napoli	NA	1966	Ugo Carputi	
C&B (B&B) factory	Novedrate	CO	1966 - 1968	Afra e Tobia Scarpa	
Dormisch brewery	Udine	UD	1967	Emilio Mattioni	
Messaggero Veneto headquarters and printing	Udine	UD	1967	Gino Valle	
Pighin factory farm	Pavia di Udine	UD	1967	Gino Valle	
warehouse in Mestre	Mestre	VE	1967	Angelo Mangiarotti	Aldo Favini
Lever Gibbs factory	Casal pusterlengo	MI	1967	Costantino Corsini, Giorgio Wiskemann	Leo Finzi, Edoardo Nova
Azienda Comunale Trasporti garage	Capodimont e	NA	1967	Giuseppe Sambito	
power plant S. Maria La Foce	S. Maria La Foce	SA	1967	Michele Pagano	Aurelio Giliberti
industrial building roof structure	Villanova d'Asti	AT	1967	Sergio Nicola	Antonio Migliasso
Attiva paint factory	PozzoloFor migaro	AL	1967 - 1970	Vittoriano Viganò	Leo Finzi, Edoardo Nova,
ARM Italia factory	Cinisello Balsamo	MI	1968	Angelo Mangiarotti	Giulio Ballio, Giovanni Colombo, Alberto Vintani
Bossi textile factory	Cameri	NO	1968	Vittorio Gregotti	Ludovico Meneghetti, Giotto Stoppino
Fiat dealership	Domegliara	VR	1968	Angelo Mangiarotti	
Gondrand centre	Pioltello	MI	1968	Aldo Favini	
IBM headquarters	Segrate	MI	1968 - 1975	Marco	Pietro Crescini
Max Market factory	Trezzano sul Naviglio	MI	1969	Giorgio Pugliese	Aldo Favini
Olivetti factories in Scaramagno, Crema and Marcianise	varie	TO	1969	Marco Zanuso, Edoardo Vittoria	Antonio Migliasso
Mollificio Bresciano factory	San Felice del Benaco	BS	1968 - 1981	Vittoriano Viganò	
Barilla factory	Parma	PR	1970	Giuseppe Valtolina, Carlo Rusconi Clerici	
LEMA factory	Alzate Brianza	CO	1970	Angelo Mangiarotti	Giulio Ballio, Giovanni Colombo, Alberto Vintani
Gio Buton liqueur factory	San Lazzaro di Savena	BO	1970 - 1971	Valtolina Rusconi Clerici	

NAME OF BUILDING	TOWN	PROV	DATES	ARCHITECTURAL AND OTHER DESIGNERS	OTHERS ASSOCIATED WITH BUILDING
Delchi factory	Villasanta	MB	1970 ca.	Techint (Milano)	
Singer factory	Monza	MB	1970 *		
Idromeccanica factory	Cologno Monzese	MI	1970 *		
Gabbioneta factory	Monza	MB	1970 *		
Center Gross	Bologna	BO	1970 *		
Busnelli factory	Misinto	MB	1970*	Roberto Ferrarin, Giancarlo Savioli	
Artemide factory	Pregnana Milanese	MI	1970*	Emma Gismondi Schweinberger	Anna Scotti Schweinberger
Driade factory	Caorso	PC	1970*	studio Lambda	
Razzo factory	Sant' Agata	BO	1970*	Ferdinando Forlay	
Magazzini Standa warehouse	Fiano Romano	RM	1971-1974		
Gabel factory	Rovellasca	CO	1972 - 1974	Vittorio Gregotti	Hiromici Matsui, Pierluigi Nicolin, Bruno Viganò
Esselunga distribution centre	Pioltello	MI	1973 - 1975	Tono Morganti	Egone Cegnar
Fantoni factory	Osoppo	UD	1973 - 1978	Gino Valle	A. Carnelutti, N. Zizzutto, C. Filippuzzi
Centro Fiorentino ingrosso	Sesto Fiorentino	FI	1973 - 1978		
Kodak factory	Caserta	CE	1974	Gigi Gho	Aldo Favini
Fiat dealership	Bussolengo	VR	1976	Angelo Mangiarotti	
Parmigiano Reggiano headquarters	Reggio Emilia	RE	1977	Guido Canali	
Bertotto Modesto textile factory	Gaglianico	BI	1977		
IBM Italia complex	Santa Palomba	RM	1979 - 1984	Marco Zanuso	
FEG factory	Giussano	MB	1978	Angelo Mangiarotti	
D&C factory	Zola Predosa	BO	1979 - 1981	Adolfo Natalini	Roberto Magris, M. Ciampi, A. Chimenti
Unifor factory	Turate	CO	1983	Angelo Mangiarotti	
LEMA 2 factory	Giussano	MB	1990	Angelo Mangiarotti	

Table 1-4: list of buildings included in the database Concrete Industrial Architecture in Italy 1950 1980, sorted by the date of construction.

F. 1-86: industrial buildings from the '50s included in the database Concrete industrial architecture in Italy 1950 1980 (author 2016)

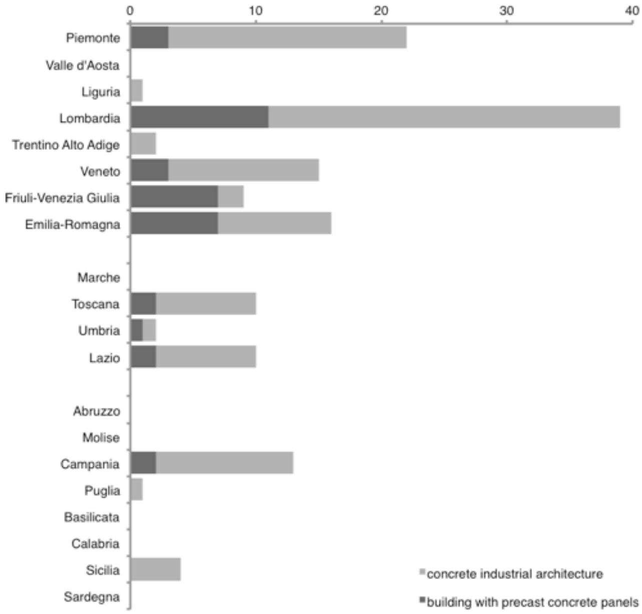
F. 1-87: industrial buildings from the '60s included in the database Concrete industrial architecture in Italy 1950 1980 (author, 2016)

F. 1-88: industrial buildings from the '70s included in the database Concrete industrial architecture in Italy 1950 1980 (author, 2016)

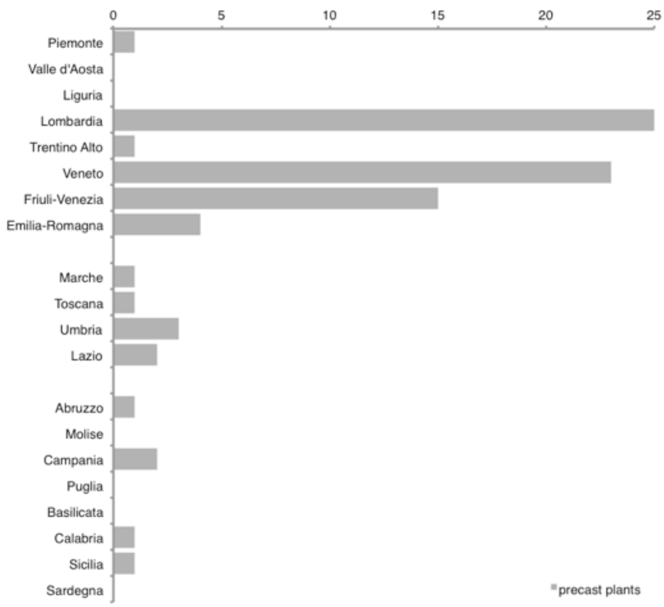
F. 1-89: buildings included in the database Concrete industrial architecture in Italy 1950 1980 and buildings made with precast concrete panels, which are presented in detail in the following paragraphs (author, 2016)

- small dots: concrete industrial architecture

- large dots: precast concrete panels



F. 1-90: buildings included in the database Concrete industrial architecture in Italy, sorted by Region and classified for the use of precast concrete panels (author, 2016)



F. 1-91: precast concrete companies operating in the period 1950-1980, as included in the database Concrete industrial architecture in Italy,, sorted by Region (author, 2016)

Notes on current condition, alternations and further proposals for existing buildings

Finally, the survey on industrial architecture has highlighted one of the most important aspects of the research, besides the recognition of significant buildings: their current condition and conservation.
In particular, the search for the actual localisation of the building - geographical coordinates and addresses - carried out through the collection of recent information and photographic documentation and also through direct investigation on the field, has allowed the verification of the condition and any possible alteration or damage to the buildings.

Several of the buildings initially surveyed, in fact, no longer exist, mainly as a result of urban regeneration initiatives which, especially during the '80s, led to their demolition or only partial preservation of them.
Many of the buildings have been subject, over time, to substantial modifications, which includes partial demolitions, additions determined by the changing needs of the production cycle, alterations of the original layout, recladding and rebranding resulting from a change of intended use, and alterations to the concrete outer surfaces as a result of repair and maintenance careless of the conservation of original formal features.
Additionally, the majority of cases shows a significant modification of the urban contexts in which the buildings are located, with the result that, regardless of their state of use and conservation, the recognisability of the constructions was greatly compromised. These modifications are mainly the accommodation of roads and infrastructure that have altered the system of access and views of the building, or redesign of the external areas, with addition of service and accessory buildings such as shelters, loading and unloading platforms, etc.
However, there are some good examples of industrial buildings that have been restored and converted and intelligently integrated into the changed context, becoming central elements of new museum complexes related to industry, modern ‘work villages’ or business management centres.
In general, the problem of physical preservation of these buildings arises in addition to the more critical one of their protection. The slump in the industrial sector has, in fact, highlighted the delicate balance between the architectural and testimonial value of the building and the use value related to the maintenance of the functionality of the facility, also in relation to the current production requirements and performance standards.

Demolition is the worst possible scenario and represents a total loss of physical, economic and cultural value. A significant case in this sense was the Morassutti warehouse in Padua, designed by Angelo Mangiarotti and Bruno Morassutti between 1956 and 1959, and demolished in 1987 due to the redevelopment of the area for the

Giotto-Auchan Center (Rinascente group) [64]. The building, at the time already considered an important company archive and industrial heritage, was a notable example of prefabrication for industrial architecture[65]. The demolition took place suddenly and during the night, probably to forestall any possible protection measures. This deplorable episode represents perfectly the attitude towards the industrial heritage of the recent past, which often neglected every possible opportunity to intelligent valorisation and reuse of these spaces.

A practice that has always characterised industrial buildings - besides their architectural and economic value - is the adaptation, extension and addition of parts for functional and productive reasons. In this sense, prefabricated industrial buildings were often designed - following modular principles - to allow further extensions: the regular structural grids ease the multiplication of the aisles to increase the functional volumes and prefabricated façade elements favour their replacement or removal to connect new blocks. However, these interventions were often realised with little consideration of the overall architectural and technological value of the building. This approach was evident in the extension for the Seleco plant in Pordenone (Gino Valle, 1967), as presented in chapter 3, in which the new storage area was seamlessly added to the existing block, reproducing identical structural elements but using a totally different type of precast concrete cladding panel.

Additionally, work aiming to correct design errors, to provide new service integrations or to meet new requirements and legal obligations might lead to large-scale modification of the interior space and organisation (such as for compliance with fire protection requirements). Even energy retrofit interventions often cause significant changes to the external appearance of the building.

Re-branding and re-cladding operations, often carried out due to changes of ownership and intended use, might also result in the total loss of architectural and cultural values. While the sense of the building may be totally subverted (i.e. from workspaces to shopping malls), its architectural features will also no longer be recognisable, as the façade is usually covered with a new cladding. Even though this approach was often a successful strategy for urban regeneration, involving buildings with little aesthetic quality, it sometimes led to less desiderable outcomes. Such was the case of the former Dapres (Celli and Tognon, 1978) facility, designed by Gino Valle (1973-1974) and converted into a shopping centre about a decade ago. The building, on the motorway to Venice, was once notable for its ‘sculptural solidity’: a rectangular block, covered with vibrant green panels enriched by thick diagonal

[64] Roverato, Giorgio, *Padova e l’occasione mancata,* online column nordesteuropa, 2009 (www.giorgioroverato.eu/A/NORDESTEUROPA/occasionemancata.pdf).

[65] Also considering that the two warehouses were designed so that they could be easily disassembled and reassembled, thanks to a research on modularity regarding both structural and cladding elements.

stripes, which echoed the landscape and modulated geometric scans by Mondrian[66]. Nowadays it is as anonymous as many other commercial spaces, and the physical additions to the original building envelope were substantial: change of colour - from green to pink -, addition of pilaster strips and false-portals, integration of shop signs (F. 1-94, F. 1-95).
Furthermore, even though other remarkable buildings were not subject to substantial modification of their use, their structures and their building envelopes, the issue of concrete deterioration often resulted in consistent coating interventions (see chapter 2), even in some of the case studies analysed.

Besides this physical alteration of industrial buildings, the issues of protection and preservation of historic, architectural and economic values have also become increasingly central. Nowadays, the protection of industrial heritage, not only of r.c. buildings, faces even more the problem of the conservation of memories and the need for refurbishment and upgrade for the new uses. A significant case in this debate is that of the Burgo paper factory in Mantova (Pier Luigi Nervi, 1960-1964), from the call for protection (finally endorsed)[67] and the recent events within the company[68].

On the other hand, in the Italian context, many projects in recent decades have shown significant outcomes with the approach of 'selective preservation' and adaptive reuse.
In this sense, one masterpiece of modern industrial architecture skilfully converted for new cultural uses is the Olivetti plant in Ivrea. The former factory was converted (1997-2001) into an open-air museum of industrial architecture by Olivetti. The ICO (ing. Camillo Olivetti) workshops were largely transformed into office space; the New ICO and the Officina H were subject to major renovations: one part now houses the activities of a mobile phone company, one part is occupied by the University of Turin and other parts are used for exhibitions and concerts. The changes in the intended use did not affect, however, the original architecture, as the site is recognized for its great value in the history of both Italian industry and architecture[69].
Other industrial sites show this positive approach towards the preservation of existing structures together with the renovation and addition of other companies' facilities. The industrial site of B&B Italia in Novedrate (Como), whose first factory was a

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[66] The Dapres and the Bergamin plant highlight the idea of Gino Valle by the importance of the colour for industrial architecture; the topic of industrial buildings and the landscape in the work of Gino Valle is however widely discussed in (Croset, 2009; Croset and Skansi, 2010).

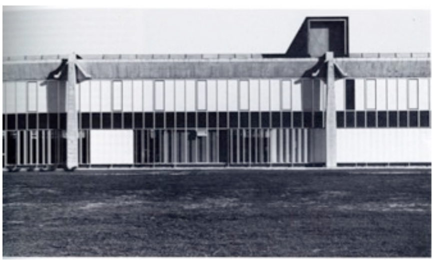
[67] Latest updates of the protection status of the Cartiera Burgo in Mantova were published on the local newspaper on the 11th November 2016 (gazzettadimantova.gelocal.it).

[68] The situation of the Burgo paper factory, between the need for protection and current perspective of reuse, is thoroughly discussed in Alzetta, Giorgio. 2016. *La cartiera Burgo di Pier Luigi Nervi a Mantova: progetto, realizzazione, vicende e prospettive di un edificio industriale simbolo del Moderno*, Master Degree Thesis, University of Udine, advisors: Anna Frangipane and Stefano Sorace.

[69] The process for the candidacy for the UNESCO World heritage list of the industrial site in Ivrea is presented in www.ivreacittaindustriale.it/officina-ico/.

prefabricated building designed by Afra and Tobia Scarpa (1968), was progressively completed with new constructions designed by notable international architectural firms: the headquarters by Renzo Piano and Richard Rogers (1971-1973), and the Research Centre by Antonio Citterio, Patricia Viel & Partners (2000-2003).
Similarly, the Benetton plant in Ponzano (Treviso) originated from the first factory designed by Tobia Scarpa and Cristiano Gasparetto in 1963-1964, which was converted in the late ‘80s into the management centre of the company[70], becoming the central element of the new ‘work village’ of Benetton (including the Children centre designed by Alberto Cambo Baeza in 2007). Additionally, from the ‘80s the Benetton Group has concentrated its production in the plants in near Calstrette of Villorba, in three industrial buildings which were also designed by Afra and Tobia Scarpa and together constitute a sort of 'town of technology’ (Morganti, 1995): the Robotized warehouse of 1980 - with again a large use of precast concrete elements - the Wool division factory of 1985 and the Jeans division factory of 1992.

Finally, it must be noted that a number of the building included the catalogue, including some well-known examples of industrial architecture in Italy are now disused and sometimes in bad conservation. It is the case, for instance, of the three Olivetti plants designed by Marco Zanuso in Scaramagno and Marcianise - the one in Crema has been partially reused by the Universty of Milan, the SIAG plant in Marcianise by Angelo Mangiarotti, the Manifattura Tabacchi in Bologna by Pier Luigi Nevi.



F. 1-92: Olivetti in Crema, 1969, M Zanuso, 1969 (Selvafolta and Alfonsi, 1986)

F. 1-93: Olivetti in Crema, 1969, M. Zanuso, current condition (Google, 2016)

F. 1-94: Dapres, Portogruaro, 1973, G. Valle (Valle and Ceccotti, 1979)

F. 1-95: former Dapres, Portogruaro, 1973, G. Valle (Google, 2015)

[70] A critical overview of the renovation of the Benetton factory is presented by Marco Mulazzani in *Allegory of prudence* (Masiero and Maguolo, 2012).

1.2.5 Precast concrete panels for industrial buildings: case-studies included in the database

Prefabricated industrial architecture in Italy is a valuable heritage of the recent past and the history of the development of precast concrete architecture for industry enable the identification of several emergent-cases in Italy, the reference area of the study. The choice of the theme is supported by the spreading of such buildings over a territory, as characterised by the widespread industrial buildings of small and medium enterprises, in addition to large industrial plants. These industrial buildings, despite their fragmentary nature and their scattering throughout the landscape, are witness to the productive vocation of many areas, and thus the recognition of some relevant works and of their importance as emergent cases is significant for a reconstruction and preservation of the traces of the manufacturing culture in the territory. Moreover, the evaluation of industrial heritage and an understanding of the history of the technology and processes predominant in the local area has enabled the identification of valuable buildings, which may then assume the role of potential centres for the re-design of suburban areas and landscape.

As a result, the buildings included in the database were chosen as case-studies from among the large number of prefabricated buildings in the country due to their remarkable presence and according to multiple criteria, which include:

- works reported in the technical publications (journals, producers' catalogues, handbooks) of the time as the best practices or successful examples of prefabricated industrial architecture;
- works included in monographic publications due to their significance in relation to theoretical formation and professional development of their author;
- works rediscovered by recent thematic studies, research, surveys and catalogues about industrial architecture / contemporary architecture in Italy;
- works which in any case emerge from the contemporary landscape due to their architectural and environmental value.

Consequently, even though the stylistic-aesthetic neutrality of precast industrial buildings constitutes the main trait of this presence, Italy possesses more than a few examples of precast architecture of great value. In fact, as discussed in the above paragraphs, right from the ‘60s, following the diffusion of precast concrete typologies, Italian architectural firms and construction companies started experimenting with prefabricated building systems and precast concrete elements for use in industrial buildings.

Many architects exploited the possibilities presented by prefabrication and standardisation, inflecting their personal modernist language into the industrial architecture. The use of factory-made precast concrete panels became therefore a way to realise spaces for industrial production that are industrial products themselves. Such is the case of several notable industrial plants designed by Gino Valle (warehouses Rex Zanussi, 1963, Zanussi works canteen and offices, 1965, Pighin wine cellar, 1967), Enzo Zacchiroli (Il Resto del Carlino printing factory, 1963-1965), and Valtolina Rusconi Clerici (Buton distillery, 1970-1971 and others).

However, other less-known but valuable industrial buildings from the period - also linked to notable Italian companies or architects - were built with a large use of prefabricated elements: the Artemide factory by Emma Gismondi and Anna Schweinberger, the Busnelli factory by Roberto Ferrarin and Giancarlo Savioli, the Razzo factory by Ferdinando Forlay, and many industrial buildings by Gino Valle (Scala factory, 1961, Sipre plant, 1962-1963, Messaggero Veneto HQ, 1967).

Other interesting factories and office buildings were designed by architectural firms and construction companies which specialised in the industrial building sector: the Delchi factory by Techint (Milano), the Sassuolo factory by studio Vandelli e Franzelli, the Driade factory by studio Lambda, the Solari factory by Valtolina and Rusconi Clerici firm, the wholesale complexes in Florence and Bologna (the Grandi Lavori construction company), the Bertotto Modesto tailoring factory (Precem company) and other buildings for small and medium-sized enterprises such as Idromeccanica, Gabbioneta and Singer factories (Pizzarotti company).

Significant special cases of prefabrication for industrial buildings designed by notable authors may be found across the country, such as the Bossi textile factory (1968) by Vittorio Gregotti, the Attiva paint factory (1967-1970) by Vittoriano Viganò and the Padua cattle market (1965-1968) by Giuseppe Davanzo.

In several of the selected buildings, the design of the original façade panels gave construction companies, clients, and designers the opportunity to introduce new technologies and brand-images for the factory. Remarkable examples of this are the Zanussi plants by Valle (1963), the Benetton factory by Scarpa (1964-1966), the Barilla plant by Valtolina and Rusconi Clerici (1970), the Esselunga warehouse (1973) and also two notable projects for ARM (1968) and LEMA (1970) by Mangiarotti.

In these cases, the original design of special panels for the façade adds value to the whole architectural character of the building, thus becoming the distinctive element of these factories. In the earlier works, the design of the façade and the conception of the detail are the innovative elements of the building and the most relevant feature according to its scale. In the latter examples, the façade component represents the farthest/final aspects of the architectural research into innovative prefabricated systems.

Prefabricated industrial buildings: fiches

The use of precast concrete cladding panels for industrial buildings was characterised, from the ‘60s, by two principal approaches: the choice of ‘standard’ panels produced by precast concrete companies, with different features and assembly solutions, and ‘special’ panels, originally designed for the specific project. The selected buildings are therefore presented separately according to this two panel types and following a chronological order.

FICHE	BUILDING	DATES	AUTHOR
	standard panels		
01	Rex Zanussi warehouses	1963	Gino Valle
02	Il Resto del Carlino printing factory	1963-1965	Enzo Zacchiroli
03	Zanussi works canteen and office	1965	Gino Valle
04	Pighin factory farm	1967	Gino Valle
05	Buton liquor factory	1970-1971	Giuseppe Valtolina Carlo Rusconi Clerici
06	Bertotto Modesto textile factory	1977	
	special panels		
07	Benetton factory	1964-1966	Tobia Scarpa
08	Sèleco factory	1966-1967	Gino Valle
09	ARM Italia factory	1968	Angelo Mangiarotti
10	Barilla factory	1970	Giuseppe Valtolina Carlo Rusconi Clerici
11	LEMA factory	1970	Angelo Mangiarotti
12	LEMA 2 factory	1990	Angelo Mangiarotti
13	Esselunga warehouse	1973-1975	Enrico D. Bona Tono Morganti

	<u>other buildings</u>		
14	Padua cattle market	1965-1968	Giuseppe Davanzo
15	Attiva paint factory	1967-1970	Vittoriano Viganò
16	Bossi textile factory	1968	Vittorio Gregotti
17	Dormisch brewery	1967	Emilio Mattioni
18	Busnelli factory	early ‘70s	Roberto Ferrarin, Giancarlo Savioli
19	Artemide factory	early ‘70s	Emma Gismondi, Anna Scotti Schweinberger
20	Delchi factory	early ‘70s	Techint (Milano)
21	Driade factory	early ‘70s	studio Lambda
22	Gabbioneta factory	middle ‘70s	Prefabbricati Pizzarotti
23	Singer factory	middle ‘70s	Prefabbricati Pizzarotti
24	Idromeccanica plant	middle ‘70s	Prefabbricati Pizzarotti
25	Centro Fiorentino ingrosso	middle ‘70s	Grandi Lavori constructions
26	Center Gross	middle ‘70s	Grandi Lavori constructions
27	IBM Italia complex	1979-1984	Marco Zanuso

Table 1-5: list of the case-studies building presented, sorted by type of panels and dates

| fiche 01

1. identity of building	
current name of building	**Rex Zanussi warehouses**
variant or former name	-
address	-
town	-
province	PD, BG, MI, PG, RM
zip code	-
country	Italia
national grid reference	45.547324, 9.232421
classification/typology	IND
protection status	-
2. history of building	
original brief/purpose	
dates	1963
architectural and other designers	Gino Valle
others associated with building	-
significant alterations with dates	-
current use	COM
current condition	various
3. description	
general description	The project originated from the regional plan for local storage and distribution units for Zanussi. The building is a modular container which consists of a warehouse and a two-storey office block, connected through a loading-unloading gallery.
construction	The building system is entirely prefabricated and the deposits can be built according to the simple assembly rules of the various components.
context	Deposits were built in various regions of Italy and in various urban or suburban environments, including Padua, Bergamo, Milan, Perugia and Rome.
4. evaluation	
technical	The deposit shows innovative design solutions, then continued and refined in subsequent industrial building. The metal frame structure is organized on a square grid of 14.40 m (12M x 12M) which can contain the office-box and the storage-box, while leaving the maximum freedom of plan and volume conformation. The façade consists of two parts: a bottom part composed of heavy concrete panels and a top part in lightweight Luxaflex panels. The walls are made up to a height of 2.20 m with prefabricated panels in r.c. and an insulation layer

(resistant to impact). This separation of the façade, already explored in other projects, is here "radicalized" to a composition of the elements in opposition, without joints and mediation: a reworking of ordinary building elements combined in an unprecedented way.

social

The plan for Rex Zanussi local branches offer to the architect Gino Valle the first opportunity to actually experiment the reproducibility of its architecture: the deposits, using the same building system, can adapt to different urban contexts, from industrial areas or urban suburbs to the country.

cultural & aesthetic

The design of the model-warehouse is not only related to the constructive rationalization, but also explores the possibilities of architectural expression for industrial buildings, which Valle suggested be "as anonymous as possible (programmed invisibility)", in order to obtain visibility and advertising customization through the contrast created by the presence of the building instead of the sign.
From the point of view of visual communication, architectural features of the warehouses were intended to highlight the building through the white of its envelope, as a pause in the polychrome sequence of industrial buildings lining the streets. "This form of absolute neutrality, defined 'non-architecture' by Valle, becomes paradoxically the most refined sign of the quality achieved by the company" (Croset, 1989).

historical

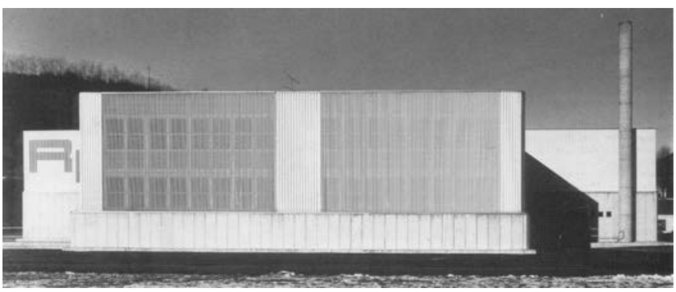
general assessment

5. documentation

principal references

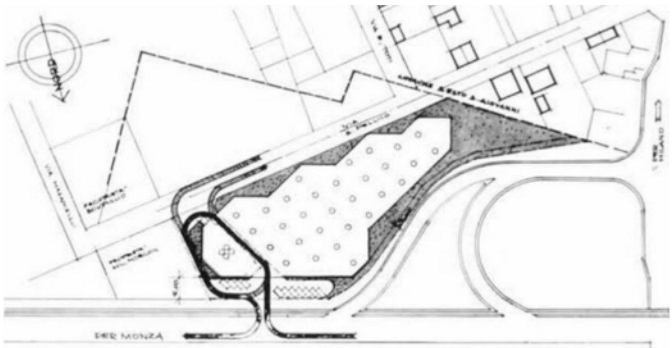
(Rykwert, 1970; Valle and Ceccotti, 1979; Croset, 1989; Croset and Skansi, 2010)

visual material attached

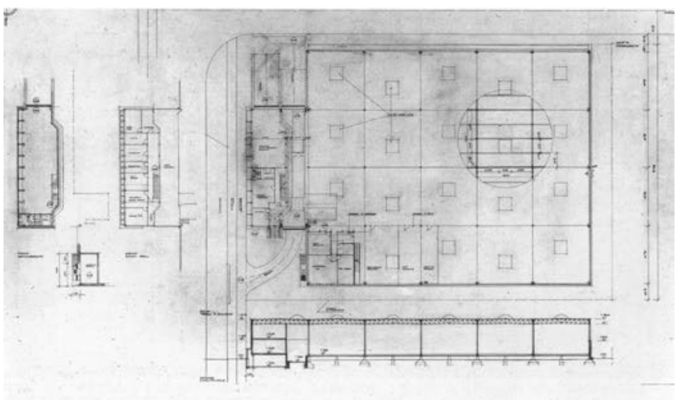


Rex warehouse (Croset, 1989)

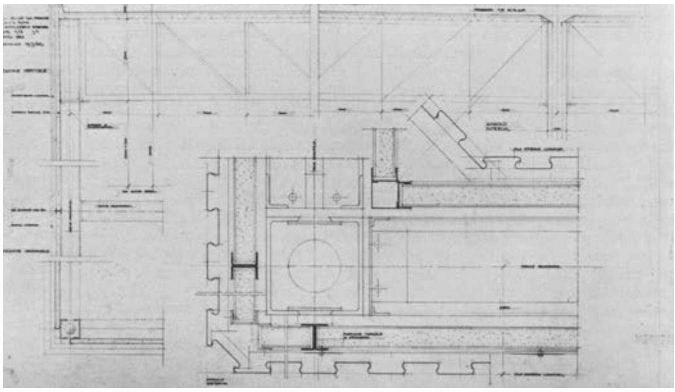
F. 1-96: Rex warehouse (Croset, 1989)



F. 1-97: plan of a Rex warehouse in Milan (Domus, 1970)



F. 1-98: plan and section of a Rex warehouse (Croset, 1989)



F. 1-99: Rex warehouse, detail (Croset, 1989)

F. 1-100: Rex warehouse in Milan, current condition (Google, 2016)

| fiche 02

1. identity of building	
current name of building	**Il Resto del Carlino printing factory**
variant or former name	Officine Grafiche il Resto del Carlino
address	via Enrico Mattei 106
town	Bologna
province	BO
zip code	40138
country	Italia
national grid reference	44.498411, 11.417810
classification/typology	IND / COM
protection status	-
2. history of building	
original brief/purpose	-
dates	1962 - 1965
architectural and other designers	Enzo Zacchiroli
others associated with building	Umberto Poluzzi; Giuseppe Rubini
significant alterations with dates	-
current use	original: sede Il Resto del Carlino
current condition	good
3. description	
general description	Printing factory designed by Enzo Zacchiroli for the newspaper Il Resto del Carlino. The plant is composed of an industrial building in which the entire production process takes places, an office building, and a service block.
construction	
context	The building is located in the eastern outskirts of Bologna, in an environment free from the constraints of coexistence with historic buildings.
4. evaluation	
technical	The production building (the printing workshop) is a two-storey block. The structure is partially prefabricated: mushroom-shaped pillars and r.c. slab for the first floor, while the roof is made of a metal frame covered with cement-asbestos, rock-wool insulation layer (5 cm), and ceiling even in Eternit. The roof is partially saw-tooth shaped, made with iron trusses, and in part flat and equipped with lighting 'ultralight' skylights (above the "composition room"). The administration building is made of mixed structure in steel and r.c. The thermal and air-conditioning building is a two-storey block, including a basement, made entirely with r.c. The cladding of all the buildings is made with prefabricated panels in r.c. with interposed insulating perlite. The material is a concrete made from marble chipping aggregates, resulting from a detailed technological study (especially with regard to the tolerances between

the panels and the metal structure).

social

cultural & aesthetic

Zacchiroli, architect of a number of modern buildings in Bologna, was awarded the IN / ARCH 1964 prize for this project.
The components constituting and connoting the façade of the building are prefabricated panels with exposed aggregate and the metal frame with vinyl covering, assembled with the utmost planarity and without plastic ornament in the detail. The architecture is thus completely expressed in the pure volumes, according to the rationalist tradition, emphasizing the horizontality by the overhang of the first floor.

historical

general assessment

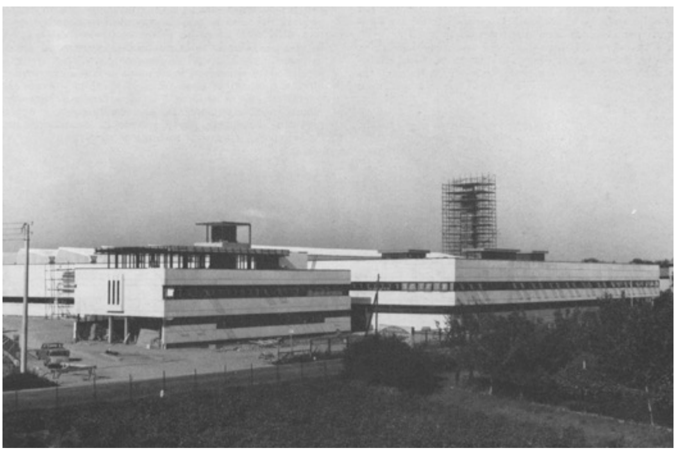
5. documentation

principal references

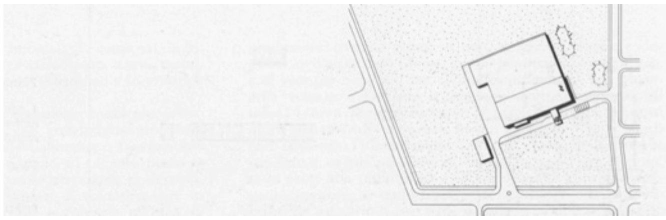
(Aloi, 1966; Koenig, 1980)

visual material attached

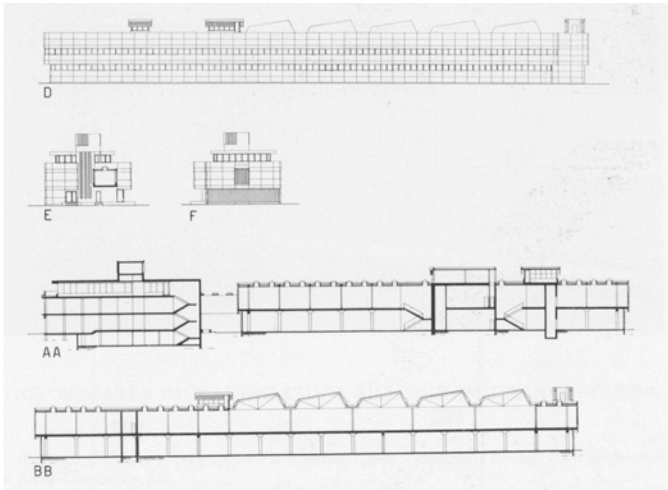
F. 1-101: Il Resto del Carlino, aerial view of the complex (Google, 2016)



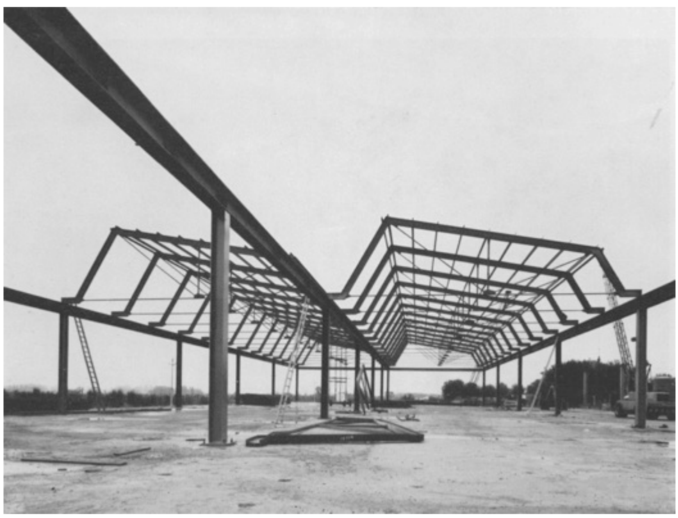
F. 1-102: Il Resto del Carlino, general view of the complex (Aloi, 1966)



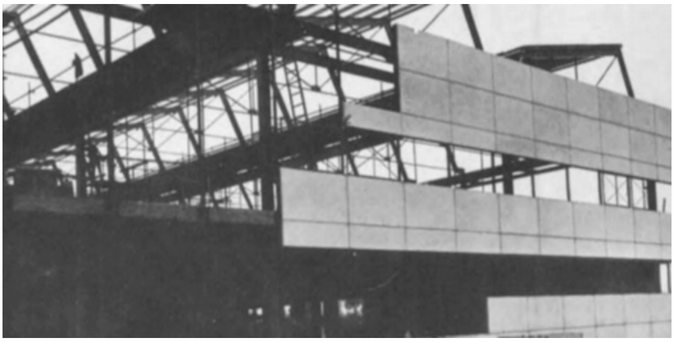
F. 1-103: Il Resto del Carlino, general plan (Aloi, 1966)



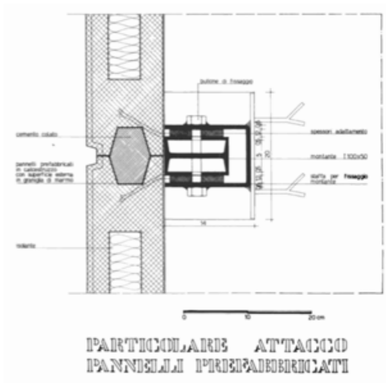
F. 1-104: Il Resto del Carlino, sections and elevations of the manufacturing building (Aloi, 1966)



F. 1-105: Il Resto del Carlino, construction (Aloi, 1966)



F. 1-106: Il Resto del Carlino, construction and detail of the panels (Koenig, 1980)



F. 1-107: Il Resto del Carlino, construction and detail of the panels (Koenig, 1980)

F. 1-108: Il Resto del Carlino headquarters (2015)

| fiche 03

1. identity of building	
current name of building	**Zanussi works canteen and office**
variant or former name	works canteen Zanussi, DIAD offices
address	corso Lino Zanussi 30
town	Porcia
province	PN
zip code	33080
country	Italia
national grid reference	45.971644, 12.622387
classification/typology	IND / COM
protection status	-
2. history of building	
original brief/purpose	1964
dates	1965 - 1969
architectural and other designers	Gino Valle
others associated with building	Altan Prefabbricati
significant alterations with dates	-
current use	original: Electrolux offices and works canteen
current condition	good

3. description

general description

The project was begun in 1964 and envisaged the creation of a ‘functional complex’ in the industrial site of Zanussi Industries in Porcia. The complex is a sequence of two-storey buildings, connected by two parallel roads.

construction

The works canteen was the first block to be built, followed by the DIAD office in 1967 and the staff office in 1969 and the gatehouse (a thermal plant was also part of the complex).
The canteen is a two-storey building, intended for 2100 users, and is characterised by a rectangular layout with a central zone for services. The system of entrance and circulation is organised by stairs and ramps, which are projected on the façade.
The DIAD offices consist of three blocks, connected by stairs and services; the staff offices, with a square plan, and the gatehouse, constitute the head of the complex.

context

The complex is enclosed in the site of Zanussi in Porcia, placed in a central position. It spreads lengthwise on an east-west axis along the Pontebbana road. While the main entrance to the site is on this street, highlighted by the Zanussi Office building, the "axes" is not visible and it is reached by passing through the gatehouse on the secondary road which surrounds the plant.

4. evaluation

technical

The general project envisaged a complex of building, based on a common constructive language. This is why the building elements are extremely limited and simplified: steel-structure with trusses based on a square grid, precast floors and roofs, and wall cladding in precast prestressed concrete panels (produced by Altan Prefabbricati). The panels lay horizontally (for the first time in the architect's work) and the windows are cast into the frame en lieu of one panel.
The basic module is 120 cm results in a structural grid of 14.40 x 14.40 meters (12M x 12M) and in the façade panels 480 cm long (4M) and 90 cm height.

social

-

cultural & aesthetic

These buildings show a constructive language taken to its extreme limit. The search for an "architectural expression as anonymous as possible” is partly negated by the emergence of several elements, which give the ‘industrial envelope’ a unique character. The entire expressive quality of this architecture seems to focus on these special elements - stairs, ramps, shadings, canopy - (Croset, 1989).

historical

general assessment

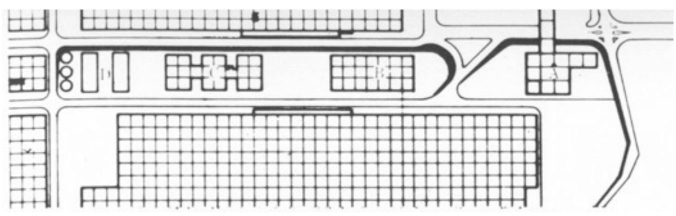
5. documentation

principal references

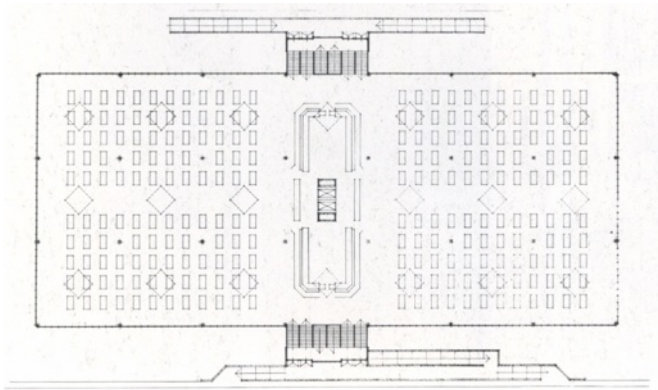
(Croset, 1989; Croset and Skansi, 2010; Valle and Ceccotti, 1979; Rykwert, 1970)

visual material attached

F. 1-109: Zanussi plant in Porcia, aerial view of the complex (Google, 2016)



F. 1-110: Zanussi plant, general plan of the axes (Croset, 1979)



F. 1-111: Zanussi works canteen, plan (Croset, 1989)

F. 1-112: Zanussi works canteen, view of the entrance (Domus, 1970)

F. 1-113: Zanussi works canteen, detail of the façade (Croset, 1989)

| fiche 04

1. identity of building	
current name of building	**Pighin factory farm**
variant or former name	
address	strada regionale 352
town	Pavia di Udine
province	UD
zip code	33050
country	Italia
national grid reference	45.983255, 13.275747
classification/typology	IND
protection status	-
2. history of building	
original brief/purpose	-
dates	1967
architectural and other designers	Gino Valle
others associated with building	-
significant alterations with dates	-
current use	original
current condition	excellent

3. description

general description

Designed as the wine cellar for the Pighin factory farm, the building consists in two parallel blocks, used as wine cellar and storeroom, connected through a roofed passage and annexed to an office block.

construction

context

The building is located along a main road, a few kilometres from the city of Udine, in a mainly agricultural area.

4. evaluation

technical

The structure is made up of metal portals, with a span of 18 m and 10.8 m high, and an interaxis distance of 4.80 m. The module used for the structure and the cladding is 1.20 m.
The cladding is made of prefabricated panels in prestressed r.c., produced off-site. The panels lay horizontally and are fixed to the metallic structure, forming a single wall (for the volume of the services) or a double wall, with ventilated cavity thanks to the holes present on the base and top of the panels (for the wine cellar).

social

The activities of the Pighin farm began in 1963, with the purchase of a 200-hectare estate in Risano (UD), covering a number of farms, including the historic cellar and the main villa, and vast vineyards and orchards. The new branch, consisting of offices and modern wine cellars designed by Valle, was built in 1967.

cultural & aesthetic

The project represents the conclusion of a cycle of research on prefabrication and aesthetic of the industrial building. The clarity of the form and the elementary volumes - two large parallel blocks connected by a covered gallery - are highlighted by the continuity of the façade, with the panels framed by the metal structure (Croset, 1989).

historical

general assessment

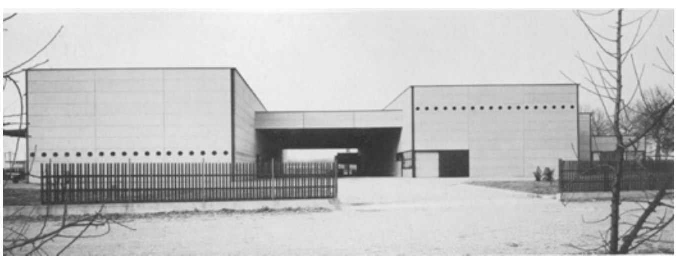
5. documentation

principal references

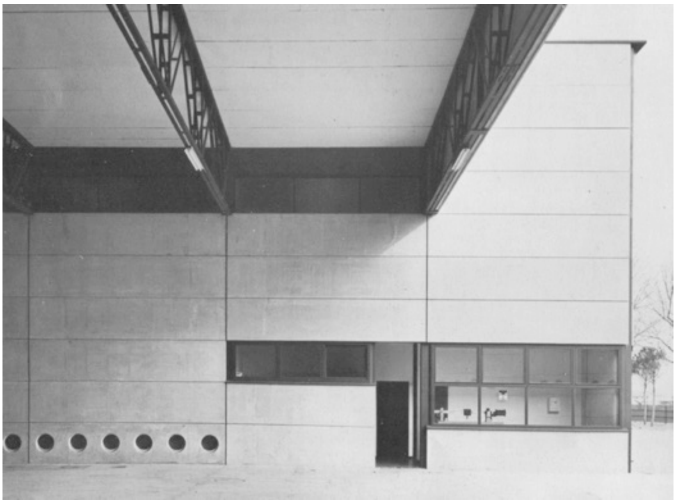
(Rykwert, 1970; Croset, 1989; Croset and Skansi, 2010; Valle and Ceccotti, 1979)

visual material attached

F. 1-114: Pighin, aerial view of the site (Google 2016)



F. 1-115: Pighin, view of the building (Croset, 1989)



F. 1-116: Pighin, detail of the façade (Croset, 1989)

F. 1-117: Pighin, factory farm current condition of the building (2016)

F. 1-118: Pighin, current condition of the building (2016)

| fiche 05

1. identity of building	
current name of building	**Buton liqueur factory**
variant or former name	
address	via Tomba Forella
town	San Lazzaro di Savena
province	BO
zip code	40064
country	Italia
national grid reference	44.440609, 11.455693
classification/typology	IND
protection status	-
2. history of building	
original brief/purpose	-
dates	1970 - 1971
architectural and other designers	Renato Bernardi Carlo Rusconi Clerici
others associated with building	-
significant alterations with dates	-
current use	original
current condition	good
3. description	
general description	The industrial complex for the production of liqueurs consists in a large building used for processing, packaging and storage, six buildings for the aging of liquors, and a single-storey building including the offices and general and specific services.
construction context	The complex is located in San Lazzaro di Savena, on the state highway 9 leading from Bologna to Imola, about 3 km from Bologna.
4. evaluation	
technical	The structure, on a square grid of 20 x 20 m, consists of prefabricated cross-shaped pillars in r.c. and metal trusses. The building intended for production is a windowless container and the light comes entirely through the joints of the roof, organized in sections on different levels in accordance with the square mesh of the structure. The façade is made of 'LECA type' prefabricated panels in concrete whit pink aggregates and a sandblasted surface. The production building is characterised by the use of vertical panels, 150 cm wide and 10 m high, with ribbed shape; a special curved element closes off the corner. In the buildings for services and offices, the cladding is made using horizontal prefabricated elements with special sections, such as a parapet and a ring beam along the perimeter.
social	The distillery "Giovanni Buton" was founded in 1820 in Bologna. The

company grew in the early years of the twentieth century and in the ‘40s started producing Vecchia Romagna, a product that earned particular renown in Italy during the economic boom. In the ‘70s the new plant was built in San Lazzaro, as a "Brandy city" of 180,000 squaremeters, the largest complex in the Italian liqueur sector and one of the five best equipped plants in Europe.

cultural & aesthetic
historical
general assessment

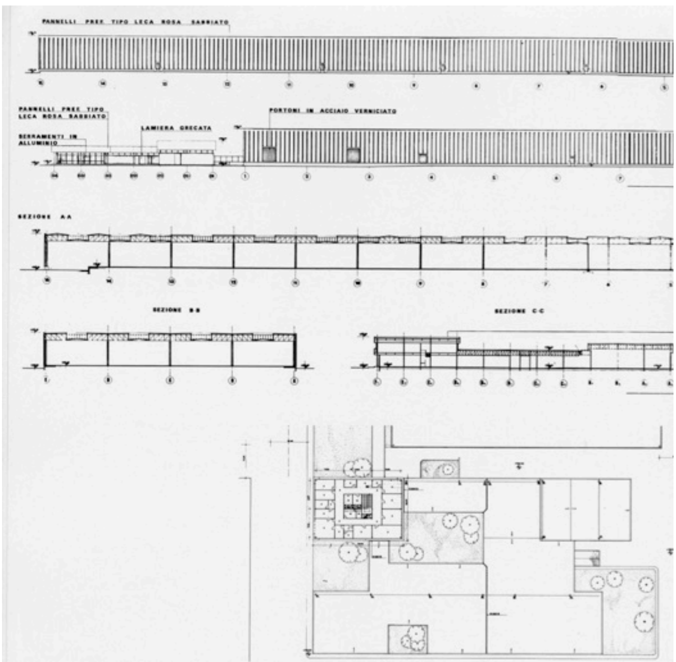
5. documentation

principal references

(Valtolina and Rusconi Clerici, 1969; Rusconi Clerici, 1972)

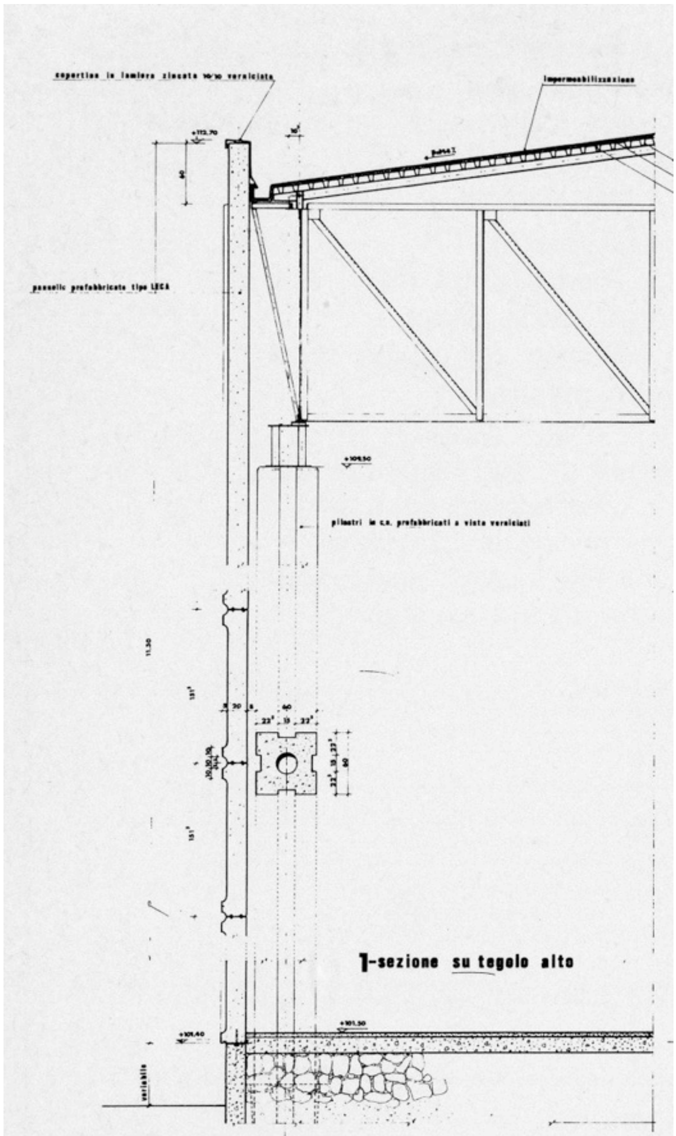
visual material attached

F. 1-119: aerial view of the complex (Google, 2016)

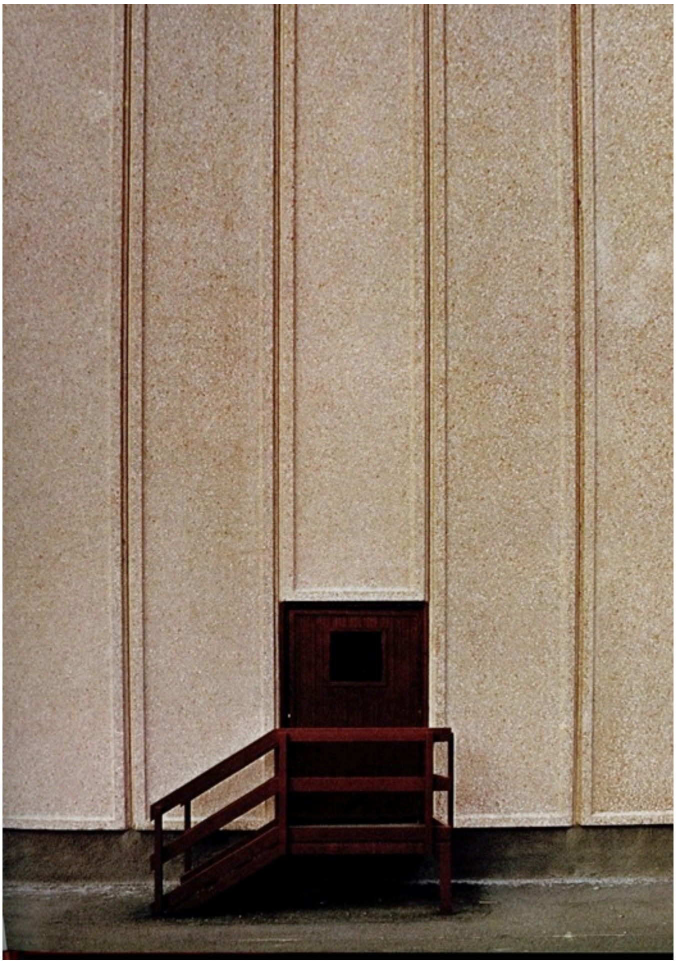


F. 1-120: Buton liqueur factory, plan, sections and elevations of the complex (Valtolina, 1972)

F. 1-121: Buton liqueur factory, view of the façade and detail of the finishing (Valtolina, 1972)



F. 1-122: Buton liqueur factory, section and detail of the panels (Valtolina, 1972)



F. 1-123: Buton liqueur factory, detail of the concrete panels (Valtolina, 1972)

| fiche 06

1. identity of building	
current name of building	**Bertotto Modesto textile factory**
variant or former name	The Place outlet
address	via Cesare Battisti 75
town	Gaglianico
province	BI
zip code	13876
country	Italia
national grid reference	45.523358, 8.092901
classification/typology	IND / COM
protection status	-
2. history of building	
original brief/purpose	-
dates	1977
architectural and other designers	-
others associated with building	PRECEM
significant alterations with dates	-
current use	Commercial
current condition	Renovated

3. description

general description

The Bertomodes factory was built in 1977 in Sandigliano (BI), where it joins the entire production of the company. The building, of 15,000 square meters, marked the unification of all the manufacturing phases of the company, from spinning to finished fabric. In 1979, the building also became the first store of the brand.

construction context

The factory is no longer located in the valley but more close to the main roads, according to the dynamics of the market and the company, seeking a more visible and accessible location for its new retail activities.
The orientation of the building does not does not follow that of the adjacent street but follows an east-west alignment.

4. evaluation

technical

The structure is organised on a square grid of 16 m x 16 m.
The façade is made with prefabricated panels in r.c., produced by PRECEM. The panels, laying vertically, are of 2.50 m wide and 7.50 m hight, in white cement, with central ribbing, so that the joint coincides with the thinnest part of the panel section.

social

The Modesto Bertotto company was the first woollens mill in the area of Biella to evolve beyond simple production, offering also tailoring and the sale to the public. Becoming a leader in the production of outerwear for men and women, and with the ambition of becoming a fashion brand, until the ‘80s it was the most important company of the sector in the area, also being a strong model for other fashion brands and designers.

cultural & aesthetic

The façades are decorated by the curved shape of the panels in white concrete produced by PRECEM. The administrative areas is distinguished by the presence of ribbon windows, integrated in the panels.

historical

general assessment

In 2005 the building was renovated and transformed into a shopping centre. The design by Beretta Associati for Ermenegildo Zegna S.p.A. led the transformation of the original building into 5,000 square meters of commercial space, obtaining a series of green courtyards, useful for increasing the lighting of spaces and organising paths and vistas within the commercial units. The original prefabricated façade was preserved and painted.

5. documentation

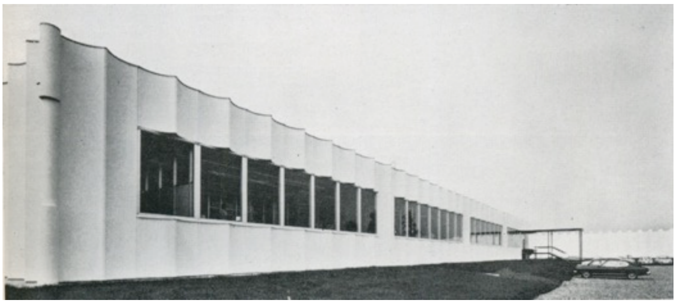
principal references

(Cislaghi and Del Lago, 1977)

visual material attached

F. 1-124: Bertotto textile factory, aerial view of the complex (Google, 2016)

F. 1-125: Bertotto textile factory, general view of the complex (Cislaghi, 1977)



F. 1-126: Bertotto textile factory, façade (Cislaghi,1977)

F. 1-127: Bertotto textile factory, new courtyard of the shopping mall (Beretta Associati, 2016)

| fiche 07

1. identity of building	
current name of building	**Benetton factory**
variant or former name	-
address	via Cavour 2
town	Ponzano
province	TV
zip code	31050
country	Italia
national grid reference	45.710602, 12.215753
classification/typology	IND
protection status	-
2. history of building	
original brief/purpose	-
dates	1964 - 1966
architectural and other designers	Tobia Scarpa, Cristiano Gasparetto
others associated with building	Carlo Maschietto; SIPRE
significant alterations with dates	via Cavour 2
current use	Administrative
current condition	good / renovated

3. description

general description

Inside the industrial site of Benetton, these knitwear production facilities are clearly indicated by their flat profile and the unique construction system. The plant consists of two parts, according to the two main functions, united by a central courtyard: administrative activities and services are contained in a small grouping of buildings in the form of a truncated pyramid, while the actual production area is contained in the large warehouse.
The entire building is windowless and the light comes only from the roof. The production building is an open-space and the various areas are characterised by different heights of the ceiling.

construction context

The building is part of the industrial settlement in Ponzano for the Benetton company, a complex which includes several buildings constructed over the years by well-known designers.

4. evaluation

technical

The building is a notable example of prefabrication: a prefabrication which tends to be integral and in which a characterising element is that the same technique was used for almost all the elements of the construction, load-bearing and not. The building system was designed and manufactured by SIPRE (UD), and includes elements in r.c. and prestressed r.c. produced through casting on long plates and movable dies on rails. The module used is for the entire construction is 82.5 cm. The main structure consists of a large beam on four supports spanning the entire plant, 85 m long and with a section of 230 x 190 cm (hollow,

also includes the air ducts).
The roof is made with two sets of beams X-shaped in partially prestressed concrete, formed by two symmetrical elements jointed with bolts, measuring 90 cm x 135 cm and a maximum length of 18 m. The beams rest on the central beam and on the perimeter walls and are positioned with a distance of 165 cm, leaving a free gap of 35 cm covered with dithered glass panels.
The walls, consisting of prefabricated panels in prestressed r.c., are bearing elements and not simple cladding. The C-section of the panels, assembled alternately with one face to the outside and the other to the inside, allows a greater resistance to loads (both vertical and action of the wind) and a height of 9 m. The continuity between the panels is assured by the saturation of joints with cement; the panels are embedded at the base in the foundation and in the summit in the T-section perimeter beam, upon which the roof rests.

social
cultural & aesthetic

"Low and extended, like the flat landscape, the building shows aspects of great architectural and constructive interest. A building which, without formalism, has a strong and clear formal aspect: the way in which the two parts are clearly separated, that reflect and accommodate the two different types of work, and in the way in which the central court connects these two parts" (Scarpa, 1966).

historical

The plant in Ponzano is the first project by Afra and Tobia Scarpa for Luciano Benetton, followed by several other projects for industrial buildings in the settlement of Villorba.

general assessment

At the end of the ‘80s, the building was converted into the management centre of the company, thanks to the relative autonomy of the original design from rigidly fixed functions, and became the central element of the new large "work village". The project still involved still Afra and Tobia Scarpa along with Greggio & Associates. The interior spaces have been reorganised with a movable system of partition and flooring, X-beams include the plant pipes, and the surfaces of exposed concrete were painted white.

5. documentation

principal references

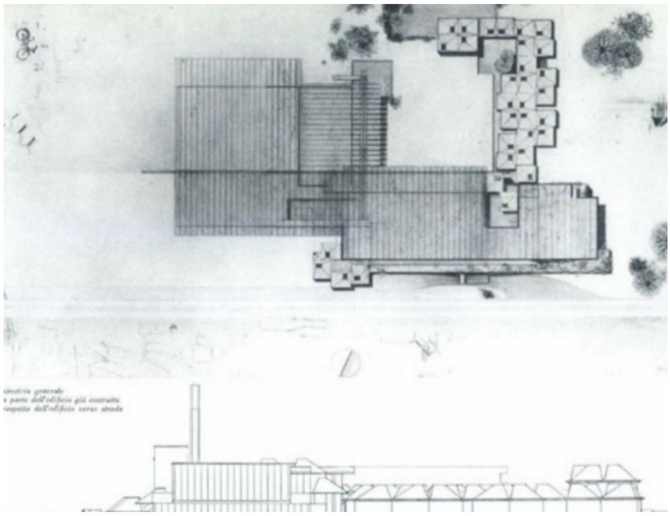
(Scarpa, 1966; Masiero and Maguolo, 2012)
atlante.iuav.it/stampa.php?x=237

visual material attached

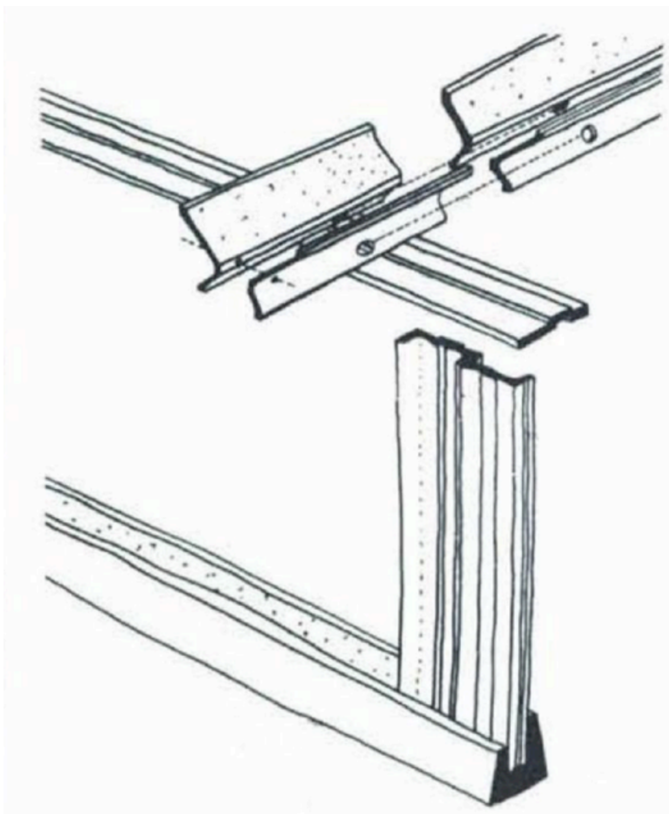
F. 1-128: Benetton factory, aerial view of the complex (Google, 2016)

F. 1-129: Benetton factory, general view (www.benetton.it)

F. 1-130: Benetton factory, general view of the building during the construction phase (Domus, 1966)



F. 1-131: Benetton factory, plan and section (Domus, 1966)



F. 1-132: Benetton factory, scheme of the prefabricated system (Domus, 1966)

F. 1-133: Benetton factory after the renovation (2016)

F. 1-134: Benetton factory after the renovation (Masiero and Maguolo, 2012)

| fiche 08

1. identity of building	
current name of building	**Sèleco plant**
variant or former name	Zanussi Elettronica plant
address	viale Treviso
town	Pordenone
province	PN
zip code	33170
country	Italia
national grid reference	45.931078, 12.647037
classification/typology	IND
protection status	-
2. history of building	
original brief/purpose	1963
dates	1966 - 1967
architectural and other designers	Gino Valle
others associated with building	Zanussi and SIPRE
significant alterations with dates	-
current use	disused
current condition	good

3. description

general description

The Sèleco plant, designed in 1966 by the architect Gino Valle, was built within the industrial area of Pordenone in Vallenoncello to accommodate the production of Zanussi electronic products and later was intended to house the production of Sèleco and Brionvega television sets, including offices, showroom and services for these activities.
The plant consists in two types of block: the main production area, which is a parallelepiped with a shed-type roof, and the offices buildings, which protrude from the main section of the factory.

construction

The project was developed from 1966, the construction were completed in 1967 with some variants and was carried out by the company Zanussi itself. The precast concrete panels were produced by the SIPRE company.

context

4. evaluation

technical

The main building, for the production, is characterised by a shed roof, made of a metal structure and precast concrete cladding along the whole perimeter. The structure is organised on a grid pattern with a module of 12.50 x 12.50 metres. The roof comprises triangular metal trusses supported by steel profiles lined with corrugated metal sheet. The cladding is made using special precast concrete element, known as ‘biscuit panel’: very tall and narrow precast reinforced concrete element which was not particularly thick and was of a peculiar curved shape.

social

The Zanussi Elettronica building (Sèleco) was an integral part of the company's policy of expansion, which involved the construction of plants in various areas of the Region, as previously explained. For the city, however, the most important aspect of the overall project was the actual location of the complex, which was intended to bring the factory closer to the workers, since most of the company's workforce lived in the residential areas to the south of Pordenone, and the aim of creating a new image of industrial Pordenone.

cultural & aesthetic

The skin of the building, characterised by the original design of the façade and the cladding elements, is definitely the distinctive character of the Sèleco factory. The façade is made of precast reinforced concrete panels, shaped and assembled according to an original system designed by Valle in 1963.
In that period, in fact, research carried out by Valle into industrial buildings (architecture reproducibility and prefabrication) focused precisely on the constructional definition of the cladding components and their assembly (Croset and Skansi, 2010). In this last case in particular the constructional choice appears for the first time combined with aesthetic considerations.

historical

The peculiar façade system was also used in the Zanussi Kitchen plant in Porcia (1964), in the *Zanussi Grandi Impianti* building in the adjacent lot and in the *SOLE* factory (1968).

general assessment

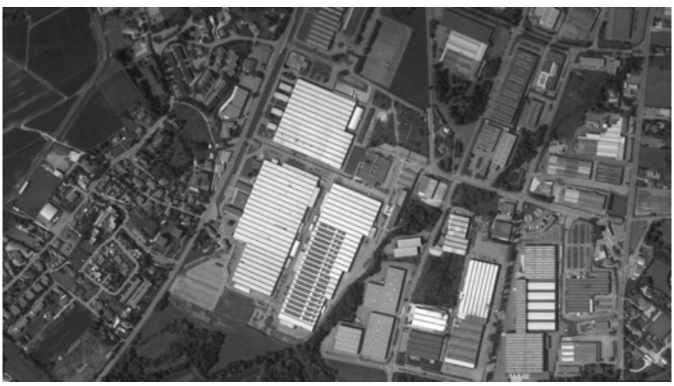
Although underused, the site is generally in good condition. The building was subject of several alterations and additions in the ‘80s and ‘90s but is however in excellent state.

5. documentation

principal references

(Croset and Skansi, 2010; Valle, 2016; Baccichet *et al.*, 2016)

visual material attached



F. 1-135: aerial view of the Sèleco plant (Google 2016)

| fiche 09

1. identity of building	
current name of building	**ARM Italia factory**
variant or former name	-
address	via Pelizza da Volpedo 107
town	Cinisello Balsamo
province	MI
zip code	20092
country	Italia
national grid reference	45.556342, 9.237440
classification/typology	IND
protection status	-
2. history of building	
original brief/purpose	-
dates	1968
architectural and other designers	Angelo Mangiarotti
others associated with building	Giulio Ballio, Giovanni Colombo, Alberto Vintani impresa GRASSETTO - AEDILIA
significant alterations with dates	-
current use	Geico plant
current condition	good

3. description

general description

The complex, designed by Mangiarotti for Armitalia, consists of three blocks with different structural characteristics. The first and the second block, intended for the offices and the warehouse, are multi-storey and based upon a rectangular grid; the third block, for production, is single-storey and organised on a squared grid.

construction

All elements of the building are made in reinforced concrete, cast on-site with reusable formwork or prefabricated off-site, transported and then assembled.

context

The building was originally located at the intersection of two main roads in the north of Milan and placed back from the streets, so that the composition of three separate volumes of different heights was visible and clear from both directions. The sizeable works on the roads carried out in recent decades have significantly changed the context and the perception of the building.

4. evaluation

technical

The structure is organised on a square grid, measuring 8.75 m x 8.75 m (7M), for the production block and a rectangular grid of 8.75 m x 4.37 for the other buildings. The structure, consisting of pillars and plates in reinforced concrete, is a perfected variant of the "Arrigoni open system" designed in 1965. The 20 plates are cast on-site using

reusable wooden formworks. In the plates there are perspex skylights with an integrated set up for the systems. The common geometric element of the three blocks is the façade, which protrudes 2.5 m from the pillars with a cantilevered structure. This solution for the façades allowed the unification of the construction type of the prefabricated cladding panels and represents the basic element of all the structural organisation. The roof of the production area rests on circular pillars - diameter of 40 cm - and is formed of 20 panles laying on the four sides on beams shaped to continue their form. At the centre of each plate there is a skylight.
The façade panels are prefabricated off-site. They are 1.25 m wide (a measurement which constitutes the basic module M of the entire project) and have a total thickness of 14 cm (two layers of concrete of 6 and 4 cm, and a 4 cm insulated layer) and are stiffened by two ribs. While being of different types and height - curved shape for the top and edge panels, flat shape for the intermediate ones - they are unified as regards the dimensions and the anchors. They are integrated with the bearing structures by angle brackets at the base, while they are free to slide vertically at the top to allow expansion. The panels allowed the building ot the entire façade without the need for further finishing, except for the sealing of the joints with mastic. The panels were, in fact, already finished in the factory: the outer surface incorporates a layer of pink aggregates (from stones and bricks) while the inner surface is plastered, the possible space for the frame is arranged in the casting (Domus, 1973).

social
cultural & aesthetic

The project takes as its starting point the constancy in the quality of the space, eliminating the differentiation within areas for work, services and administration. This also justifies the persistent image of the cladding panel that continues in an homogenous manner throughout the façade. It is a "three-dimensional" cladding that might refer to an aeronautical rather than architectural construction (Burkhardt, 2010). His curved shape at the top also leads to the solution for the water drainage on the roof. The panels are anchored at the top so that they do not touch the ground, marking the perimeter of the building with a strong shadow value at the base; this detail, together with the disappearance of the eaves, evokes the idea of a railway carriage - a sensation also emphasised by the shape of the integrated windows (Bona, 1988).

historical
general assessment

The building is now the headquarters of the Geico company. The façades have been completely plastered with red coating.

5. documentation

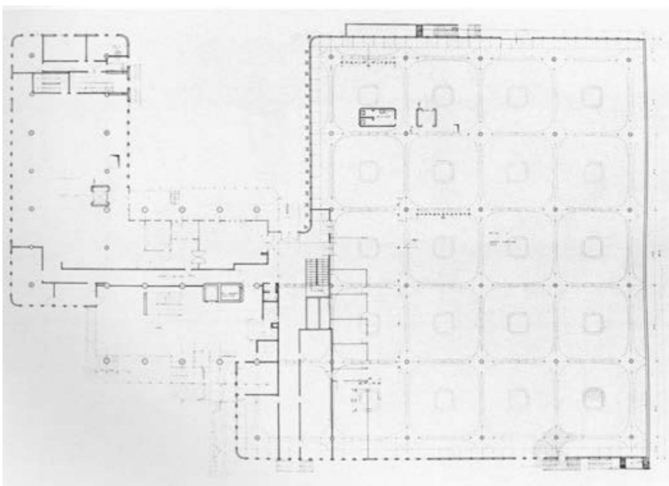
principal references

www.architetturadelmoderno.it/scheda_nodo.php?id=601
www.lombardiabeniculturali.it/architetture900/schede/p4010-00277/
(Bona, 1988; Burkhardt, 2010; Cuscianna, 1973; Mangiarotti, 1973)

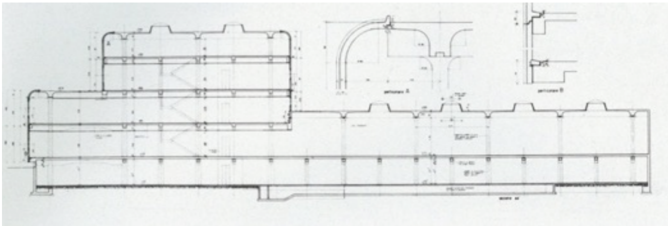
visual material attached

F. 1-136: ARM Italia, aerial view of the complex (Google, 2007)

F. 1-137: ARM Italia, general view of the building (IUAV Archivio Progetti)

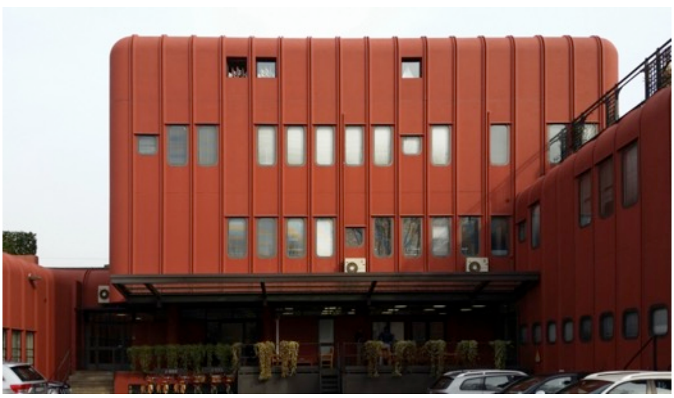


F. 1-138: ARM Italia, plan of the building (Burkhardt, 2010)

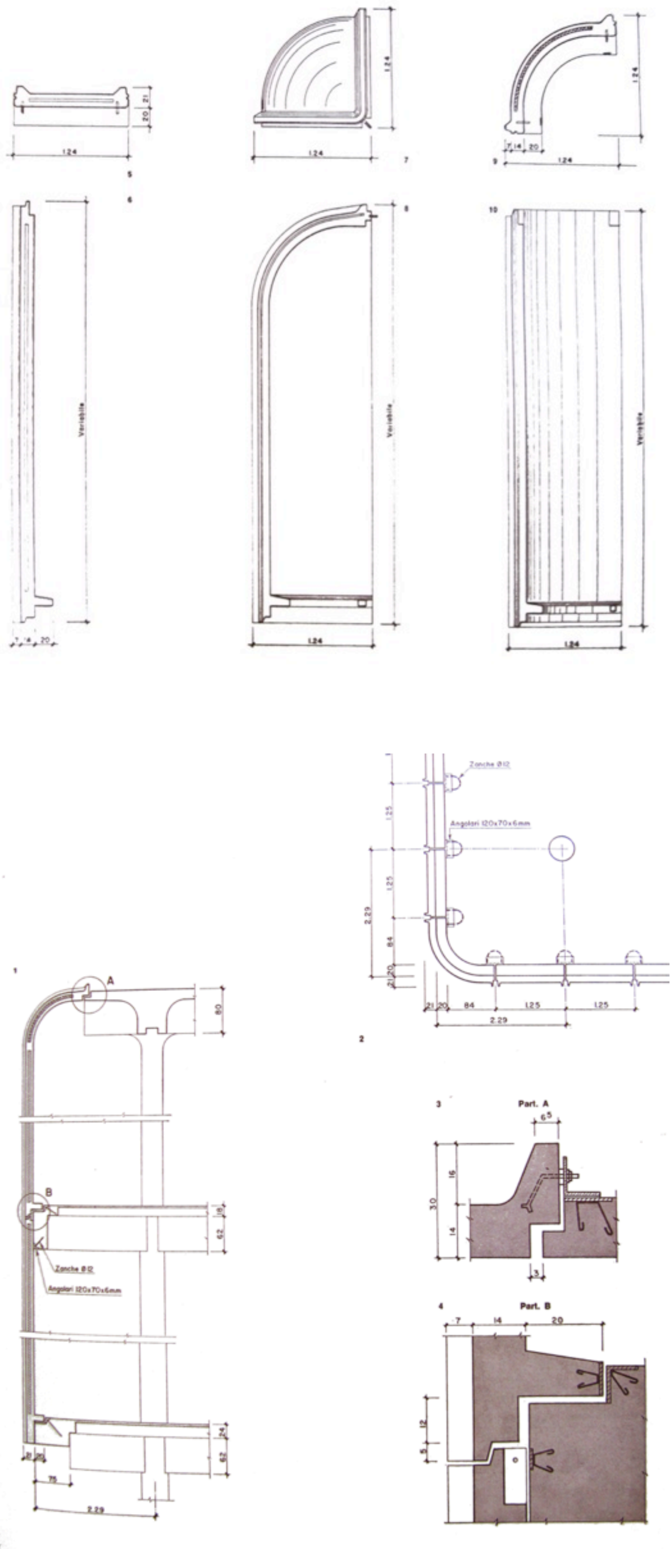


F. 1-139: ARM Italia, section of the building (Burkhardt, 2010)

F. 1-140: ARM Italia, façade (IIC, 1973)

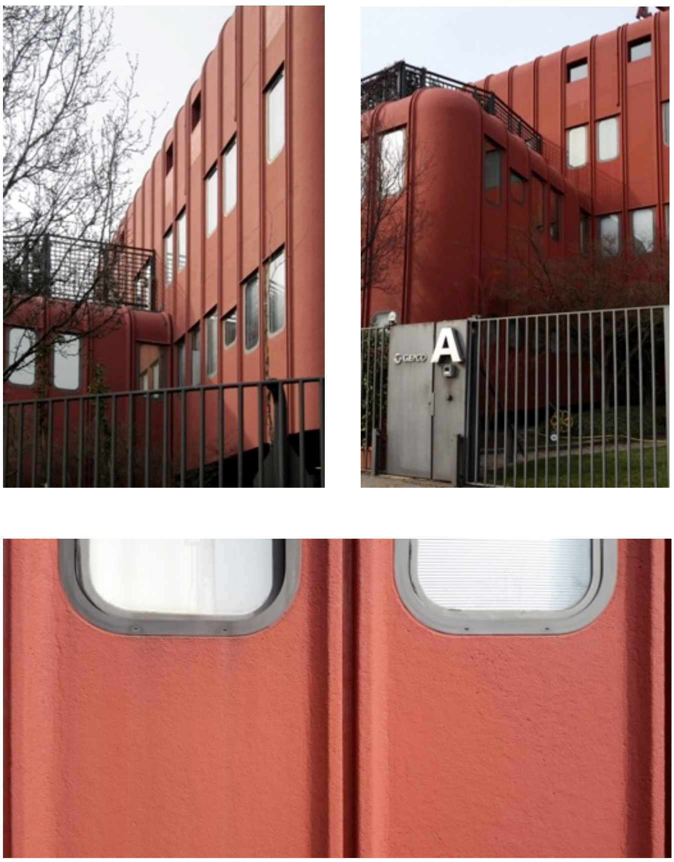


F. 1-141: ARM Italia, façade (2015)



F. 1-142: precast concrete panels used in the ARM Italia factory, detail(Cuscianna, 1973).

F. 1-143: ARM Italia, construction (Domus, 1973)



F. 1-144: ARM Italia, current condition (author, 2015)

| fiche 10

1. identity of building	
current name of building	**Barilla factory**
variant or former name	
address	via Mantova 166
town	Parma
province	PR
zip code	43122
country	Italia
national grid reference	44.827951, 10.371020
classification/typology	IND
protection status	-
2. history of building	
original brief/purpose	-
dates	1970
architectural and other designers	Valtolina Rusconi Clerici
others associated with building	Prefabbricati PIZZAROTTI
significant alterations with dates	-
current use	original: Barilla factory
current condition	good
3. description	
general description	The building consists of two large adjacent buildings for production and storage of products, which are connected to other buildings used for a works canteen and offices. The layout of the building, characterized by a C-shape, was in fact determined by the needs of a building for the production, a warehouse and a connecting body between the two.
construction context	The plant is located a few kilometres from Parma, alongside the A1 highway (Autostrada del Sole).
4. evaluation	
technical	The building is made essentially with a series of prefabricated standard components in reinforced concrete (beside the roofing): pillar, main beams, secondary beams, façade panels. The structure is based on a grid of 16 m x 16 m, with a height of 7 or 12 m. The specific requirements of the façade were solved through a double wall, which internally consists of precast concrete ribbed panels, rounded at the base to join the floor, and externally of self-supporting panels in white concrete, fixed only at the base. The design of the façade system included 25 different prefabricated elements consisting of panels of a standard height of 9.60 m or 12.60 m and a width of 2.00 m or 1.40 m, and special panels to be integrated to the openings or to the corners (the last actually cast on site). Given the particular shape of the panels, the junction is solved with a "double female" type of joint and an additional connecting element with

silicone sealing. All the components, due to their particular size, were prefabricated on-site using formwork in polyester reinforced with wood fibres (previously obtained from a wooden model). The panel is made of white cement and white marble aggregates (Zandobio), the surface finish is obtained by sandblasting. Given the brightness of the material, the entire façade was covered with water-repellent surface treatment at the end of the construction.

social

The '60s and '70s were for Barilla an important period of expansion and innovation, also through advertising (their many advertisements on the Italian TV advertising show 'Carosello' were an example of communication and powerful impact strategy).
The new plant in Pedrignano was built in this period as "the largest pasta factory in the world", an example of innovative communication policy and corporate image.

cultural & aesthetic

In the Barilla factory the architectural connotation of the building is based on the design of the façade elements, prefabricated panels in white cement concrete (IIC, 1973). The choice of colour and the form of the panels, with the particular curved and tapered shape, also characterise the image of the building in relation to the large scale of the complex. The building is furthermore a successful example of how "the component admits its own autonomy to the point of merely contain, as an enclosure, the complexity of the volumes of the internal machinery" (Domus, 1972).

historical

general assessment

The building is still used as a production facility by the Barilla company; it has not been substantially altered and its condition is excellent.

5. documentation

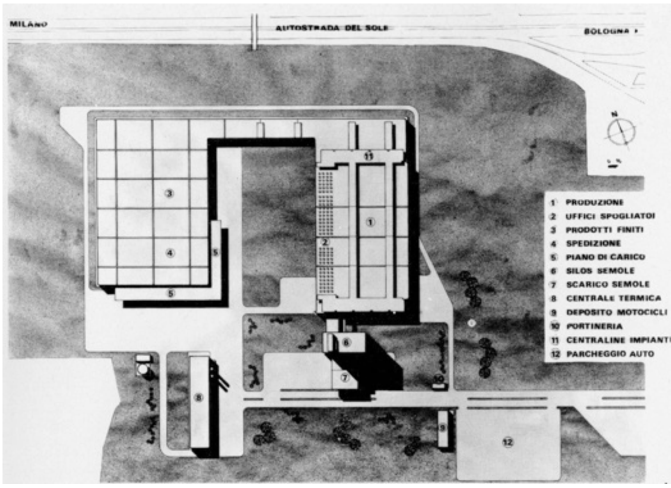
principal references

(Faccio, 1973; Rusconi Clerici, 1972)

visual material attached

F. 1-145: Barilla factory, aerial view of the complex (Google, 2016)

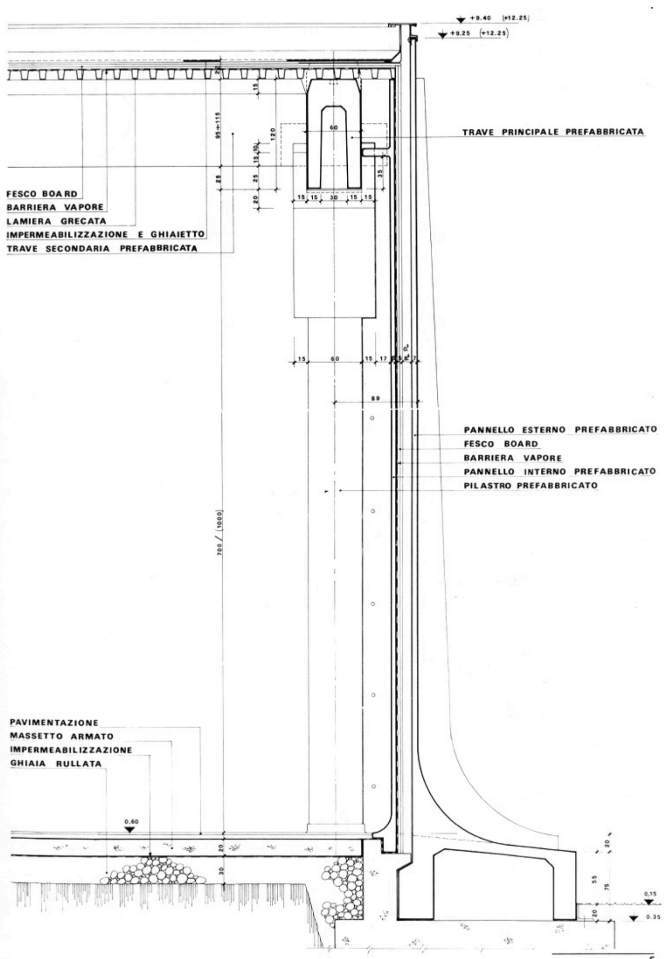
F. 1-146: Barilla factory, general view of the complex (Rusconi Clerici, 1972)



F. 1-147: Barilla factory, plan of the complex (Rusconi Clerici, 1972)

F. 1-148: Barilla factory, construction of the façade (Valtolina, 1969)

F. 1-149: Barilla factory, precast concrete panels before the assembly (Valtolina, 1969)



F. 1-150: Barilla factory, detail of the façade system (Rusconi Clerici, 1972)

| fiche 11

1. identity of building	
current name of building	**LEMA factory**
variant or former name	-
address	via Statale Briantea 2
town	Alzate Brianza
province	CO
zip code	22040
country	Italia
national grid reference	45.760622, 9.204160
classification/typology	IND
protection status	-
2. history of building	
original brief/purpose	-
dates	1970
architectural and other designers	Angelo Mangiarotti
others associated with building	Giulio Ballio, Giovanni Colombo, Alberto Vintani impresa ISOCELL
significant alterations with dates	-
current use	original
current condition	good

3. description

general description

This factory for the production of integrated furniture systems accommodates the entire production cycle, from raw materials to packaging. The structure was built according to the U70 system, designed and patented by Mangiarotti and marketed by Isocell, based on the fundamental idea of the trilith and made with of precast concrete elements: pillars with capitals, beams, roof slab. The prefabricated roofing elements, with oval skylights and cantilevered parts, enable the interior lighting and the creation a projecting roof. The system also incorporates a range of cladding solutions: wall panels, glazed panels, and window panels.

construction

The plant is entirely made with prefabricated components, factory-made and transported and assembled by the same manufacturer (Isocell). The system is characterised by very rapid assembly, which, for example, permits the installation and fastening of a beam in about 15 min.

4. evaluation

technical

The structure was entirely made with prefabricated r.c. components, according to the U70 system, characterised by the reduction to 70 cm of the thickness of plate, beam and capital of the pillar. The structural grid is rectangular, of 9 x 18 m. The pillars are of 7.55 m maximum height and 55 cm square section, with fluting to accommodate the

systems; the beams in prestressed concrete, 150 cm in width and constant height of 75 cm, have different spans depending on the structural grid and the projected parts.
The prefabricated r.c. panels reproduce the rhythm and modularity of the structure, with a width of 149 cm, a maximum thickness of 17.5 cm and height 5.50 m. All the panels are the same size but in three different versions: an opaque panel, a transparent glazed panel, a panel with window. The ribbing of the opaque panel reproduces the shape of the transparent glazed panel. No surface treatment was applied on prefabricated elements.

social
cultural & aesthetic

«An evolution of the integral prefabrication system developed earlier for Elmag in Lissone led the way towards more sophisticated technical, functional and formal results, thanks to several significant changes made to the main components. The most interesting innovation, if compared to previous or common practice for this construction type, is the inversion in the length of the beam and roofing segment» (Burkhardt, 2010).

historical

The building represents the first application of the U70 building system in its former version, used later in the headquarters of Unifor in Turate (Como) in 1983 and in the second Lema factory in Giussano (Milano) in 1990.

5. documentation

principal references

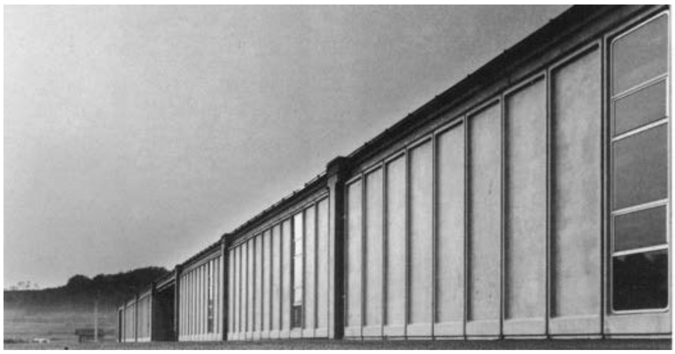
(Mangiarotti, 1975; Bona, 1988; Burkhardt, 2010)

visual material attached

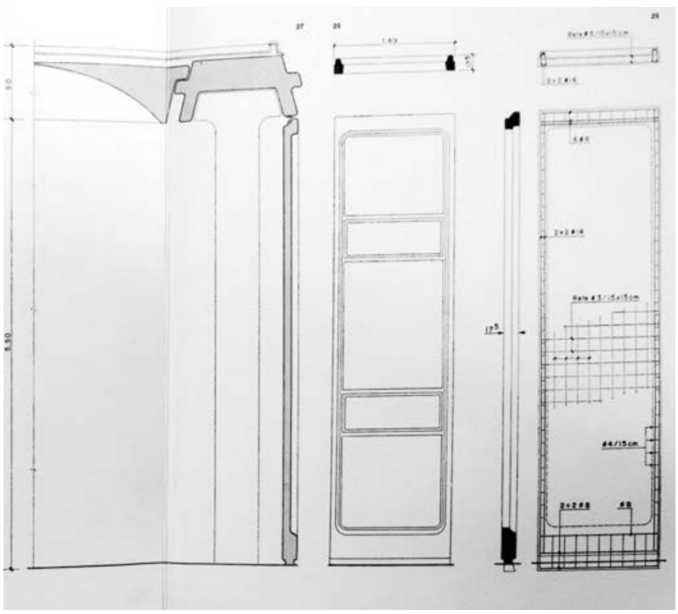
F. 1-151: LEMA factory, aerial view of the building (Google, 2012)

F. 1-152: LEMA factory, general view of the building (Mangiarotti,1975)

F. 1-153: LEMA factory, façade (www.studiomangiarotti.com)



F. 1-154: LEMA factory, façade (Burkhardt, 2010)



F. 1-155: LEMA factory, façade system (Mangiarotti, 1975)

| fiche 12

1. identity of building	
current name of building	**LEMA second factory**
variant or former name	-
address	via dell'Artigianato 12
town	Giussano
province	MI
zip code	20833
country	Italia
national grid reference	45.682318, 9.195202
classification/typology	IND
protection status	-
2. history of building	
original brief/purpose	-
dates	1990
architectural and other designers	Angelo Mangiarotti
others associated with building	-
significant alterations with dates	-
current use	original
current condition	good
3. description	
4. evaluation	The factory in Giussano is the second built for the LEMA company using the U70 Isocell system. The project represents the peak of a long study of prefabricated building systems in reinforced concrete, and in this building the remarkable potential of this structure is even clearer. The building is in fact the most recent version of the U70 building system designed and used for the first time in the LEMA factory in Alzate Brianza (CO) and then applied for the headquarters of Unifor in Turate (CO). Compared to the previous two buildings, the components here were slightly modified - from a dimensional point of view - to achieve the performance required according to current regulation. The organisation of the building on two storeys leads to higher pillars and variations in the façade, with a cladding system that duplicates the previous one, with the addition of a glass wall on the first floor constituting the front of the offices.
5. documentation	
principal references	(Burkhardt, 2010)
visual material attached	

F. 1-156: LEMA factory, aerial view (Google, 2012)

F. 1-157: LEMA factory, general view of the building (Burkhardt, 2010)

F. 1-158: LEMA factory, façade (Burkhardt, 2010)

| fiche 13

1. identity of building	
current name of building	**Esselunga distribution centre**
variant or former name	magazzini generali supermarkets
address	via Giambologna 1
town	Pioltello
province	MI
zip code	20096
country	Italia
national grid reference	45.488300, 9.316171
classification/typology	IND / COM
protection status	-
2. history of building	
original brief/purpose	-
dates	1973 - 1975
architectural and other designers	Enrico D. Bona Tono Morganti
others associated with building	Egone Cegnar Impresa Morganti
significant alterations with dates	-
current use	original
current condition	good

3. description

general description

The building is the general centralised warehouse of the Esselunga supermarket chain. It is a large pavilion of 220 x 140 m. The building is a windowless container, in which the light is provided by the skylights in the central part of the roof. The façade is almost entirely opaque and uniform, the only exceptions being the entrance area, covered by a canopy, and the offices, revealed by the presence of windows.

construction

The building was built by the Morganti construction company which, from the '60s, collaborated with the Caprotti Manufacture. The works on the Esselunga (then Italian Supermarkets) warehouse in Pioltello were followed by those for the warehouse in Sesto Fiorentino and then by the construction of several retail outlets in Lombardy and Tuscany.

context

Another identical warehouse for Esselunga was built in Sesto Fiorentino.

4. evaluation

technical

The structure is made with prestressed r.c. elements, with a modular grid of 20 x 20 m. The roof is made of large metal panels with a layer of polyurethane insulation. The façade is made with prefabricated r.c. panels, 2.50 m wide and 15 m high. The project proposed the production of these original façade panels, characterised by a round

shape at the top, as a formal solution originating from by functional requirements - the possibility of fixing of the panels to the edge beams so that they were hanging from the bearing structure. The panel was proposed in two versions: a completely opaque panel or one with circular and oval windows.
The panels (like the beams) were produced on-site through through two specially-designed metal formworks. Each panel could be stripped, with the finished surface, after a few hours of curing time, and this allowed the mould and the assembly of 4 panels in 24 hours.

social

In 1957 the world-renowned graphic designer Max Huber created the logo with the long "S" for the newborn "Supermarket Italiani spa", from which the current name "Esselunga" - Long S. The first supermarket opened in town was followed by suburban stores, including those of Pioltello and Sesto Fiorentino built by Morganti company and presented in several publications of the time. The link between Esselunga and architecture and design was consolidated in the ‘80s, when they began collaborating with Ignazio Gardella (creating about 40 shops and two offices), followed by that of other major architectural firms such as Luigi Caccia Dominioni, Norman Foster, Renzo Piano, Mario Botta, Fabio Nonis, Vico Magistretti. Thus many of the 140 buildings for the supermarket company are unique architectural structures that qualify the urban environment.

cultural & aesthetic

The building is a simple and rational structure, adequate to the main function of 'storage' in its scale and in the organisation of spaces. The only exceptions to this uniformity are the entrance canopy and the offices, characterised by the presence of circular or oval windows; these elements indicate the functional organisation of the interior space and highlight the study of aesthetic and architectural quality for the building.
The choice of modular prefabricated cladding is enriched by the original design of the panel: on the one hand, the concave cross-section moves the façade, breaking the firmness of the volume and concealing the joints, and, on the other hand, the curved top forms the crowning element of the building.

historical
general assessment

Among the interventions on the building, in recent times a energy retrofit of the roof was carried, increasing the thermal insulation through a new lightweight package roof (non-woven fabric - vapor barrier - insulation in polyurethane sheets - non-woven fabric - waterproof layer in polyester reinforced PVC), fastened with appropriate nails to the existing roof structure.

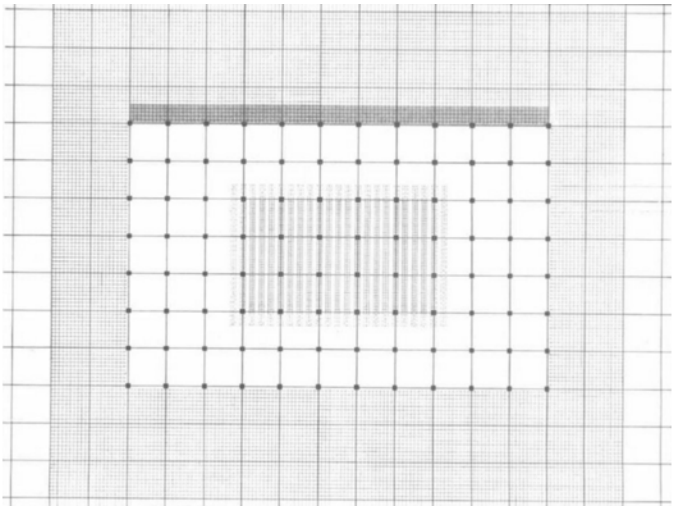
5. documentation

principal references

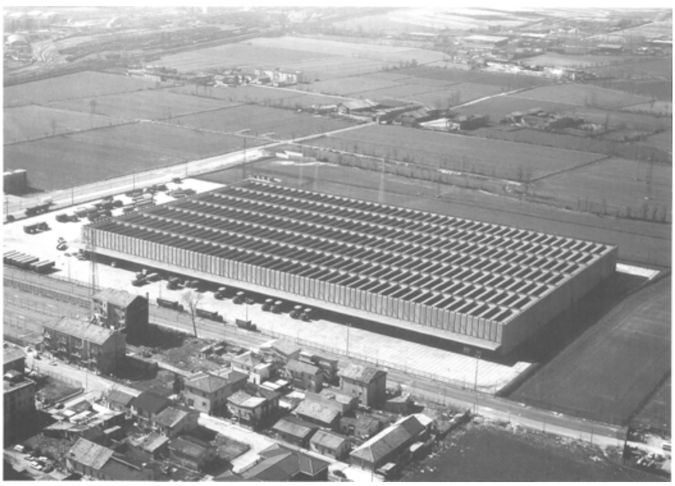
(Cislaghi and Del Lago, 1977; Bona and Morganti, 1975)

visual material attached

F. 1-159: aerial view of the Esselunga warehouse in Pioltello (Google, 2016)



F. 1-160: Esselunga warehouse, plan (Domus, 1975)



F. 1-161: Esselunga warehouse, aerial view of the complex (Archive Impresa Morganti)

F. 1-162: Esselunga warehouse, view of the entrance (Domus, 1975)

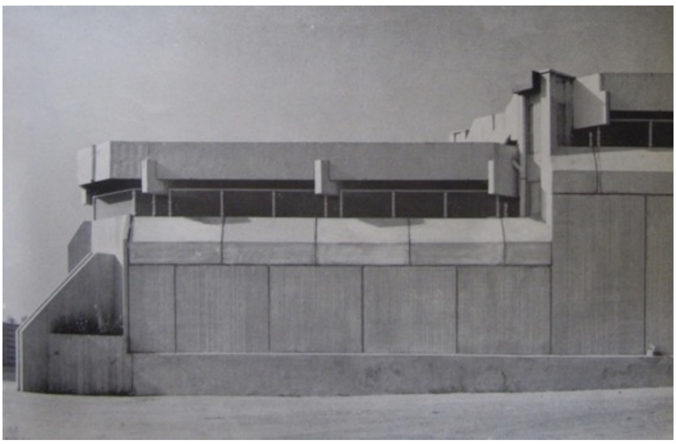
F. 1-163: Esselunga warehouse, construction phases and detail of the panels (Archive Impresa Morganti)

F. 1-164: Esselunga warehouse, current condition (author, 2015)

F. 1-165: Esselunga warehouses, current condition (author, 2015)

| fiche 14

1. identity of building	
current name of building	**Padua cattle market (*foro boario*)**
address	via Tassinari 1 Padova PD 35136 Italia
national grid reference	45.415518, 11.854825
classification/typology	IND
2. history of building	
dates	1965-1968
architectural designers	Giuseppe Davanzo
others	
current use	disused
current condition	not good
3. description	
4. evaluation	The building, interesting also for the construction technique, plays on the height variation of the individual modular elements - pillars, prefabricated roof elements and cladding panels.
5. documentation	
principal references	(Davanzo, 1970; Davanzo, 1971)
visual material attached	



F. 1-166: Padua cattle market (IIC, 1971)

F. 1-167: Padua cattle market (2014)

| fiche 15

1. identity of building	
current name of building	**Attiva paint factory**
address	SS dei Giovi 57/59 · Pozzolo Formigaro · AL · 15068 · Italia
national grid reference	44.821696, 8.748664
classification/typology	IND
2. history of building	
dates	1967-1970
architectural designers	Vittoriano Viganò
others	Leo Finzi, Edoardo Nova
current use	original
current condition	good
3. description	The factory reveals the designer's attention in defining simple but qualifying solutions to functional and technological themes, organising the project on a modular path (plan and elevation) and studying the assembly of the components - roof, cladding panels, skylights (Polano, 1996).
4. evaluation	
5. documentation	
principal references	(DOMUS, 1970) www.architetturadelmoderno.it/scheda_nodo.php?id=170

visual material attached


F. 1-168: Attiva paint factory (Domus, 483/1970)

| fiche 16

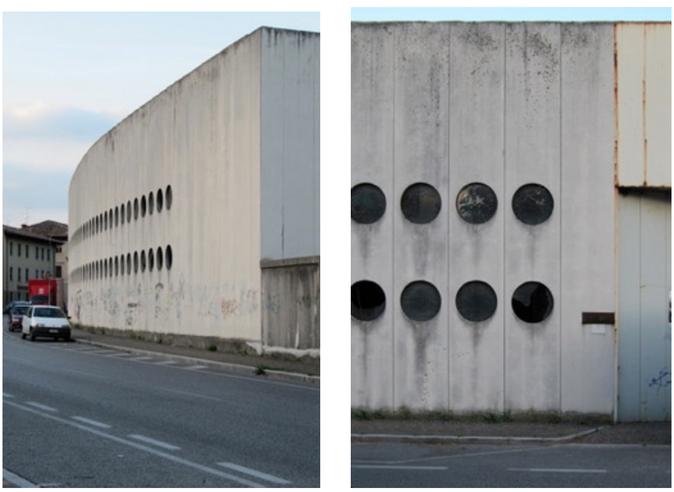
1. identity of building	
current name of building	**Bossi textile factory**
address	Strada Michelona 9 Cameri NO 28062 Italia
national grid reference	45.499933, 8.673024
classification/typology	IND
2. history of building	
dates	1968
architectural designers	Vittorio Gregotti
others	Ludovico Meneghetti, Giotto Stoppino
current use	original
current condition	good
3. description	Cladding made with panels in precast concrete with exposed aggregates.
4. evaluation	
5. documentation	www.architetturadelmoderno.it/scheda_nodo.php?id=419
principal references	(Gregotti, 1972)

visual material attached

F. 1-169: Bossi textile factory (Polano, 1996)

| fiche 17

1. identity of building	
current name of building	**Dormisch brewery**
address	via Bassi 10 Udine UD 33100 Italia
national grid reference	46.068584, 13.226540
classification/typology	IND
2. history of building	
dates	1967
architectural designers	Emilio Mattioni
others	-
current use	disused
current condition	bad
3. description	
4. evaluation	The building is an example of original and innovative use of prefabricated concrete panels for an irregularly shaped building, to create a façade which is not flat but curved, to accommodate the shape of the lot and the urban ring road, track of what was once the city walls.
5. documentation	
principal references	www.ipac.regione.fvg.it fiche 617
visual material attached	



F. 1-170: Dormisch brewery (author, 2014)

| fiche 18

1. identity of building

current name of building — **Busnelli factory**

address — via Kennedy 41 Misinto MB 20826 Italia

national grid reference — 45.659287, 9.068689

classification/typology — IND

2. history of building

dates — early ‘70s

architectural designers — Roberto Ferrarin, Giancarlo Savioli,

others — ALTAN

current use — original

current condition — good

3. description — The cladding and the roofing were made with the same components: double-T precast concrete elements, 2.50 m width and 17 m maximum height.

4. evaluation

5. documentation

principal references — (Corsini, 1972)

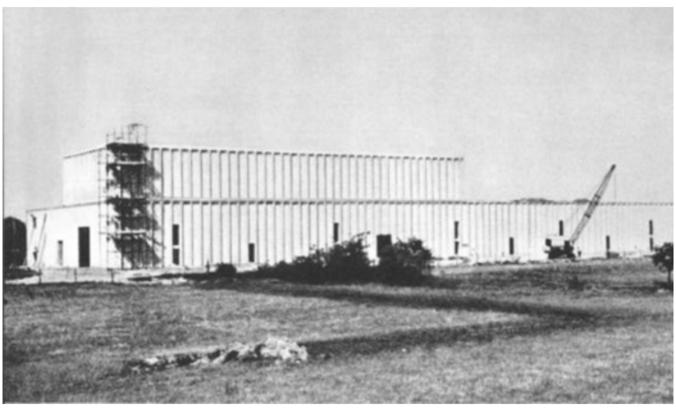
visual material attached

F 1-171: Busnelli factory (Domus, 1972)

| fiche 19

1. identity of building	
current name of building	**Artemide factory**
address	via Bergamo 16 Pregnana Milanese MI 20010 Italia
national grid reference	45.503687, 8.993454
classification/typology	IND
2. history of building	
dates	early ‘70s
architectural designers	Emma Gismondi Schweinberger, Anna Scotti Schweinberger
others	ISOCELL
current use	original
current condition	good
3. description	Rectangular structural grid, 17.50 x 10.00 meters. The same precast concrete element was used for the cladding and the roofing.
4. evaluation	
5. documentation	
principal references	(Corsini, 1972)

visual material attached

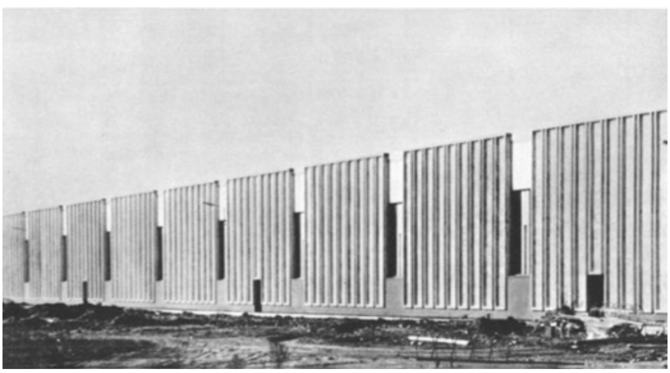


F. 1-172: Artemide factory (Domus, 1972)

| fiche 20

1. identity of building	
current name of building	**Delchi factory**
address	via Raffaello Sanzio 19 Villasanta MB 29852 Italia
national grid reference	45.600145, 9.311095
classification/typology	IND
2. history of building	
dates	early ‘70s
architectural designers	Techint (Milano)
others	Bonomi e Vecchi
current use	Tagliabue Gomme
current condition	good
3. description	
4. evaluation	
5. documentation	
principal references	(Corsini, 1972)

visual material attached

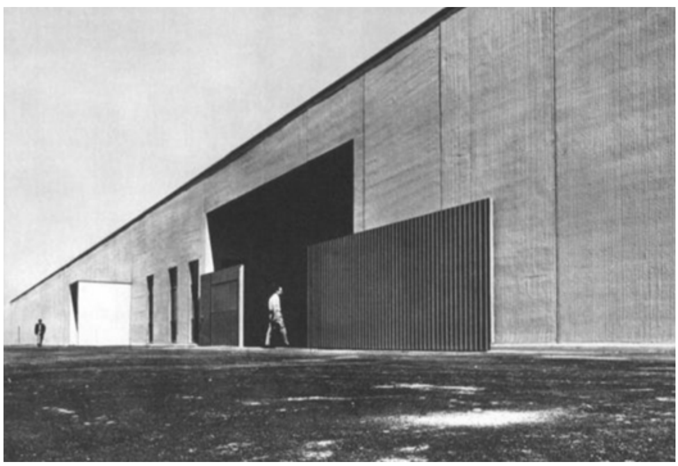


F. 1-173: Delchi factory (Domus, 1972)

| fiche 21

1. identity of building	
current name of building	**Driade factory**
address	Strada Padana inferiore Caorso PC 29012 Italia
national grid reference	45.042915, 9.824075
classification/typology	IND
2. history of building	
dates	early ‘70s
architectural designers	studio Lambda
others	ASTORI
current use	original
current condition	good
3. description	
4. evaluation	
5. documentation	
principal references	(Corsini, 1972)

visual material attached

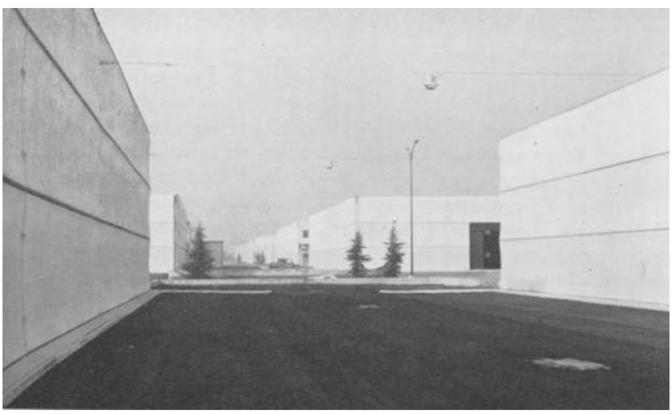


F. 1-174: Driade factory (Domus, 1972)

| fiche 22

1. identity of building	
current name of building	**Center Gross**
address	zona artigianale Funo Bologna Bo 40050 Italia
national grid reference	44.590251, 11.375278
classification/typology	IND
2. history of building	
dates	middle ‘70s
architectural designers	
others	IMPRESA GRANDI LAVORI
current use	original
current condition	good
3. description	The horizontal panels are characterised by the special shape of cross-section (meniscus shaped on the façade on the street side and ribbed on the interior façade), which underline the horizontal extension of the buildings.
4. evaluation	
5. documentation	
principal references	(Cislaghi and Del Lago, 1977)

visual material attached

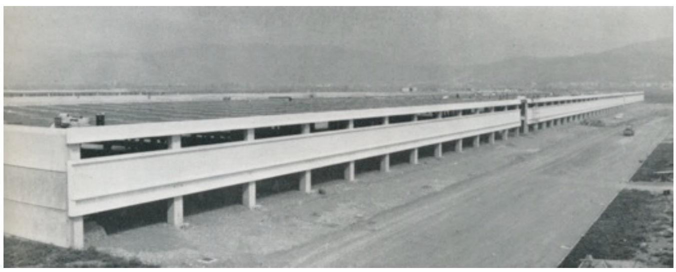


F. 1-175: Center Gross (Cislaghi, 1977)

| fiche 23

1. identity of building	
current name of building	**Centro Fiorentino Ingrosso**
address	via Senna Sesto Fiorentino FI 50019 Italia
national grid reference	43.812443, 11.170697
classification/typology	IND
2. history of building	
dates	middle ‘70s
architectural designers	
others	IMPRESA GRANDI LAVORI
current use	original
current condition	good
3. description	The horizontal panels are characterised by the special shape of cross-section (meniscus shaped on the façade on the street side and ribbed on the interior façade), which underline the horizontal extension of the buildings.
4. evaluation	
5. documentation	
principal references	(Cislaghi and Del Lago, 1977)

visual material attached



F. 1-176:Florence gross center (Cislaghi, 1977)

F. 1-177: Florence gross center (2016)

| fiche 24

1. identity of building	
current name of building	**Gabbioneta factory**
address	via Pompei Monza MB 20900 Italia
national grid reference	45.577225, 9.317642
classification/typology	IND
2. history of building	
dates	
architectural designers	
others	PREFABBRICATI PIZZAROTTI
current use	original
current condition	good
3. description	The façade is characterised by the special shape of the precast concrete panels: the cross section of variable thickness at the base and the top of the panels create a sculptural effect which marks the foundation and the top of the building.
4. evaluation	
5. documentation	
principal references	(Cislaghi and Del Lago, 1977)

visual material attached

F. 1-178: Gabbioneta plant (Cislaghi, 1977)

F. 1-179: Gabbioneta factory (author, 2015)

| fiche 25

1. identity of building	
current name of building	**Singer factory**
address	via Sicilia 98 Monza MB 20052 Italia
national grid reference	45.583946, 9.312216
classification/typology	IND
2. history of building	
dates	
architectural designers	
others	PREFABBRICATI PIZZAROTTI
current use	other industrial and commercial activities
current condition	good
3. description	The façade is characterised by the special shape of the precast concrete panels: the cross section of variable thickness at the base and the top of the panels create a sculptural effect which marks the foundation and the top of the building.
4. evaluation	
5. documentation	
principal references	(Cislaghi and Del Lago, 1977)

visual material attached

F. 1-180: Singer factory (Cislaghi, 1977)

F. 1-181: Singer factory (author, 2015)

| fiche 26

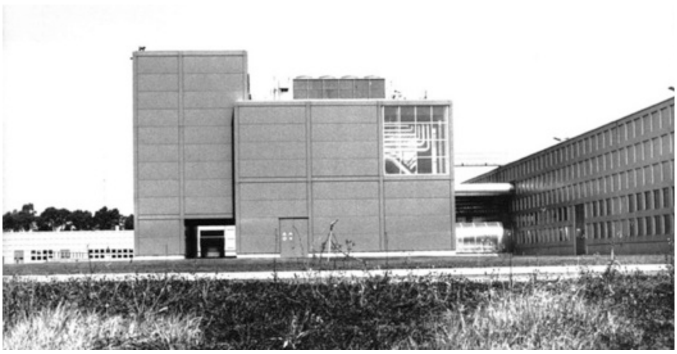
1. identity of building	
current name of building	**Idromeccanica plant**
address	Cologno Monzese MI Italia
national grid reference	non individuato
classification/typology	IND
2. history of building	
dates	
architectural designers	
others	PREFABBRICATI PIZZAROTTI
current use	
current condition	
3. description	The façade is characterised by the special shape of the precast concrete panels: the cross section of variable thickness at the base and the top of the panels create a sculptural effect which marks the foundation and the top of the building.
4. evaluation	
5. documentation	
principal references	(Cislaghi and Del Lago, 1977)

visual material attached

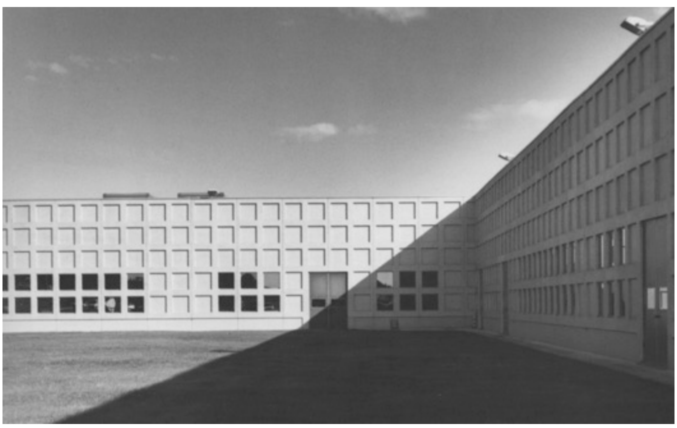
F. 1-182: Idromeccanica plant (Cislaghi, 1977)

| fiche 27

1. identity of building	
current name of building	**IBM Italia complex**
address	via Ardeatina, 2479 Santa Palomba RM 00134 Italia
national grid reference	41.695360, 12.595573
classification/typology	IND
2. history of building	
dates	1979 - 1984
architectural designers	Marco Zanuso
others	
current use	Partially disused
current condition	Good
3. description	The bearing structure consists of beams and columns organised upon a square grid of 14.40 meters. The roof is made by alternating linear opaque components and skylights. The cladding consists in the serial repetition of a modular precast concrete elements, in different colours: grey squared panels - with integrated windows too - for the production block and flat rectangular panels for the towers.
4. evaluation	
5. documentation	
principal references	
visual material attached	



F. 1-183: IBM complex in Rome (www.archivio.unita.it)



F. 1-184: IBM Italy, Rome, I, 1979-1980, M. Zanuso (Castronovo and Greco, 1993)

2 REDEVELOPING INDUSTRIAL BUILDINGS: FROM PROTECTION TO UPGRADE AND REDESIGN

2.1 The protection of industrial heritage

The discussion on prefabricated industrial architecture underlined a consideration of the meanings and values of these works of ‘contemporary industrial archaeology’. Although these constructions constitutes a building stock characterised by seriality and uniformity, sometimes even works of particular architectural value emerged, as significant examples of a flourishing historical and cultural situation, technological development, or theoretical research and design practice of notable authors.

The recognition of these values of industrial architecture has reached full maturity in recent years, especially with the initiatives for documentation and valorisation of twentieth century architecture, the issues of protection and conservation - recommendation for intervention - for these works appear to be part of an investigation still open.

The issue of protection of the industrial heritage results, in fact, articulated and sometimes problematic, involving different monuments of the industrial age ranging from the typical 'industrial archaeologies' to the recent factories, like prefabricated industrial buildings subject of this study. The disciplines around the preservation of industrial architecture have developed in the European context since the '80s, also thanks to the activity of organizations and associations involved on the topic, up to the current approaches to preservation, valorisation and reuse (paragraph 2.1.1). Several institutions have dealt with the major aspect of cataloguing the heritage, following the development of policies and guidelines carried out those context which were historically more conscious and committed to these themes, like the British one (paragraph 2.1.2).

In Italy, the activities related to the documentation and the protection of industrial heritage are promoted and coordinated primarily by the Ministry and Superintendences, but there are also many research projects and studies in local areas dedicated to the documentation and promotion strategies. The different degrees of protection provided by the Italian regulatory framework (paragraph 2.1.3) show, in fact, different possibilities, involving national and/or local and municipal authorities and various legal measures and planning instruments. In addition, specific problems arise regarding the preservation of twentieth century architecture, with respect to which the current regulatory framework reveals several critical points (age limit, effectiveness of protection measures).

In that, the case of the architectural heritage in the Friuli Venezia Giulia region (paragraph 2.1.4) results a useful element to compare current approaches and an opportunity to implement cataloguing and protection proposals for a quite extensive and sizable industrial heritage, characterised by a number of valuable buildings. This case study also allows a convincing overview of the situation of modern industrial architecture, including some prefabricated buildings, within the local industrial heritage.

2.1.1 Knowledge and preservation of industrial heritage in Italy and Europe

The discipline of Industrial archaeology was born in Britain between 1950 and 1960, as a method and investigative tool for the study of the territorial identity of industrial communities. The interest in this field of study arose in relation to the progressive abandonment of the industrial areas and the debate on the demolition of notable industrial buildings[71].

Industrial archaeology was initially defined as "a field of study concerned with investigation, surveying, recording and, in some cases, with preserving industrial monuments" (Buchanan, 1972). Since its introduction, it appeared a multidisciplinary science which involves the study of the different signs of industrial revolution (machines, buildings, technologies) and, moreover, the assessment of the meaning of industrial monuments in the context of social and technological history. This is why it was later described as an ‘archaeology of the present’, since the industrial production is still a dominant fact of contemporary age, which continues leaving tangible traces of its history.

In Italy, the interest in the field emerged approximately twenty years later, when the country opened up to the studies on popular tradition and the rural world and went through a particular socio-political period, characterized by the abandonment of large industrial sites and workers' protest. The attention to the buildings of industrial archaeology increased, in particular, with the international conference in Milan (1977) and the exhibition "Remains of a Revolution" organized by the British Council (1978), however preceded by essays such as "Art and Industrial Revolution" by Enrico Castelnuovo (1969). The topic assumed the characteristics of an interdisciplinary field of study since the pioneer work of museology experts, such as Massimo Negri, art historians as Eugenio Battisti[72], economists as Renato Covino and architectural historians as Aldo Castellano (Mazzotta, 2004; Ciuffetti and Parisi, 2012; Maspoli, 2014). The constitution of the Italian Society for Industrial Archaeology (with the aim of documenting and surveying the industrial heritage) reinforced the definition of the subject, developed in those yeas, as the whole complex of physical remains witnessing the organization of industry on the territory, to be understood not as isolated elements but in relation to local changes arising from industrial development (Negri and Negri, 1978).

[71] Conventionally, the first studies by Green and Rix (1967) and the case of the cast-iron arc of the Eutson station in London in 1960.

[72] Eugenio Battisti 1986 also curated the exhibition “Il luogo del lavoro" at the Triennale di Milano.

The successive transition from the concept of *industrial archaeology* to that of *industrial heritage* marked a significant change of approach (Ronchetta and Trisciuoglio, 2008; Ciuffetti and Parisi, 2012). The development of methodological tools for preservation and valorisation is, in fact, intended as the attribution of symbolic, cultural, economic and environmental values to the industrial assets, also in relation to the transformation of their function. The contemporary approach implies therefore a process which does not end in the identification and recognition of values but involves an assessment based on the opportunities for regeneration and redevelopment (Mazzotta, 2004; Maspoli, 2014). The emerging interest on industrial heritage, since the '80s, has suggested, in addition, the widening of the field of study of the subject, in order to include, for instance, industrial buildings from various ages. Thus studies and research on the industrial heritage consider, in addition to abandoned industrial buildings, mainly from the nineteenth century, also the physical remains of the recent industrial activities, such as 'modern' factories and sites.
This transition highlights also new vision, which is oriented towards both the productive system of the territory and individual monuments of industry. As a consequence, many studies and actions for the preservation of industrial heritage are now focused on the territorial system and landscape as a whole (Dansero *et al.*, 2003; Ciuffetti and Parisi, 2012).
The new perspective also reassert the former multidisciplinary approach, which involves the history of buildings and sites as well as the history of building techniques, of the material and immaterial culture, and of the tangible and intangible value of industrial architecture as cultural heritage. According to the Nizhny Tagil Charter (TICCIH, 2003), the industrial heritage consists, in fact, in the remains of industrial culture, holder of historical, technological, social, architectural or scientific values; this wide field includes industrial sites, buildings and architecture, such as factories, mills, mines and sites for processing and refining raw material, warehouses and stores, workshops, energy plants, transport infrastructures, including machineries and equipment, spaces for social activities related to the industry such as workers' housing, churches and schools, as well as industrial landscapes, products and processes, and documentation of the industrial society, such as companies' archives (Douet, 2012).
This integrated approach to the culture of industry is, indeed, consistent with the prospect of the Italian Code of Cultural Heritage and Landscape[73], which considers both tangible and intangible values, from architecture to the other signs of the production cycles or the industrial archives.

As well known, internationally, various organisation and associations for industrial heritage carry on activities and initiatives to preserving, conserving, investigating, documenting, researching, interpreting, and advancing education of the industrial

[73] Code of Cultural Heritage and Landscape, Legislative Decree no. 42 of the 22nd of January 2004, Italian (updated with subsequent amendments and supplements thereto).

culture. In this context, the International Committee for the Conservation of the Industrial Heritage (TICCIH) is the world organization for industrial heritage, recognised by the International Council on Monuments and Sites (ICOMOS), which aims also to promote international cooperation in the field. The TICCIH, with the Nizhny Tagil Charter for the Industrial Heritage (TICCIH, 2003) defines the key concepts and fundamental methods of industrial heritage and industrial archaeology: the definition of industrial heritage, its valules, the role of identification, recording and research, procedures for legal protection, issues of maintenance and conservation, initiatives for education and training and also communication and interpretation.
In the national context, the discussion on the topic and its specific issues is carried on, for example, by the Italian Association for the Archaeological Industrial Heritage [74], especially through its journal *Patrimonio Industriale.* The last issue of the journal, in particular, was dedicated to *Cement and cement plants in Italy* (2014); the essays included centre on the preservation and valorisation of industrial heritage linked to concrete and concrete production and highlight new tools to understand and assess this heritage, which overcome its link to overbuilding and spread of concrete constructions.

The activity of international and national organizations for the industrial heritage helps to contextualise the present study within the current trends and growing interest towards industrial architecture. The relevance of the topic of the protection and valorisation of the contemporary industrial heritage is, in fact, also highlighted by several studies and research recently presented at national and international conferences organized and promoted by these organisations.
However, in the Italian context, the renewed awareness of the issues of abandonment and neglect of industrial heritage is reflected in many initiatives, which range from online promotion activities to editorial initiatives for the knowledge and documentation of industrial assets[75]. The need to investigate systematically the phenomenon of neglected industrial heritage in the country has recently resulted in the proposal for the creation of a national 'map of abandonment'[76].

[74] Italian Association for the Archaeological Industrial Heritage, *Associazione Italiana Patrimonio Industriale* - AIPAI, www.patrimonioindustriale.it.

[75] These interesting and appealing initiatives range from the documentation of significant sceneries, as the "Still Alive" project on industrial ruins photography (www.st-al.com), to the promotion of activities related to heritage in danger, as the "Save Industrial Heritage" association (www.saveindustrialheritage.org), or otherwise to the promotion and communication of virtuous recovery and regeneration strategies (www.urban-reuse.eu).

[76] The proposal was discussed, among other things, during the conference held in Rome in October 2016 *Il Patrimonio industriale in Italia. Da spazi vuoti a risorsa per il territorio* - industrial heritage in Italy. From empty spaces to a resource for the territory.

2.1.2 Reconnaissance and recognition of relevant industrial assets as cultural heritage

The process of understanding and documenting the industrial heritage implies initiatives for the knowledge and recognition such as mapping and cataloguing buildings and other architectural remains of industry. Over the years these actions have become even more widespread, especially in European countries which are facing increasing industrial abandonment, and organised through the definition of specific methodologies. The criteria for the recognition are, in fact, a precondition for protection strategies and planning. In this sense, the most valiant approach assume a multicriteria perspective and a territorial scale, as adopted in the English context, characterised by a long culture of attention to industrial heritage (Maspoli, 2014) and thus becoming and influential reference internationally.
English heritage[77], in fact, summarises in several designation-listing selection guides, dedicated to different types of structures, the reasons why buildings and structures meet the criteria for national protection[78]. Consideration about the meanings of industrial structures for designation involves several key-points which summarise the current approach for industrial heritage (English-Heritage, 2011). They take into account physical remains, at different scales, such as industrial contexts, architecture and equipment, as well as other 'intangible' signs of the industrial culture of technological and historical interest (table Table 2-1).

THE WIDER INDUSTRIAL CONTEXT	More than with many building types, industrial structures should be considered in their wider setting. Taking the example of the cotton industry of Greater Manchester, this might extend through all stages: the landing and storage of cotton bales; transporting these via canal or railway to the factory; carding, spinning and weaving on integrated or separate sites; finishing, storing and packing goods; distributing them to the consumer; and recycling waste products. All play their part, and each building needs to be seen within this broader context.
REGIONAL FACTORS	This involves a regional perspective in the selection of buildings and sites in order to achieve a representative sample for each sector of an industry. It also requires the identification of

[77] English Heritage in 2015 separated into two different bodies: a new charity retaining the name English Heritage, which looks after the National Heritage Collection (www.english-heritage.org.uk), and a newly named organisation called Historic England, which continues the statutory role of giving advice to owners, local authorities and the public, and championing the wider historic environment (historicengland.org.uk).

[78] The Listing selection guides for the different building types are available online at historicengland.org.uk/listing/selection-criteria/listing-selection/.

	regional specialism and the study of survivals related to these industries, such as the boot and shoe industry of Northampton, or the steel-working sites of Sheffield, which will often have strong claims to note on a national level.
INTEGRATED SITES	If the process to which a building is related involved numerous components, then the issue of completeness may become overriding. On an integrated site that is relatively incomplete, a single surviving building is unlikely to justify listing unless it is important in its own right (for instance, it is an innovatory structure or is of architectural quality). On the other hand, an exceptionally complete site (perhaps with water systems and field monuments as well as buildings) may provide such an exceptional context that it raises the importance of buildings that might otherwise not be listable.
ARCHITECTURE AND PROCESS	An industrial building should normally reflect in its design (plan form and appearance) the specific function it was intended to fulfil. Many processes, especially in the twentieth century (for instance, car or bicycle manufacture), simply house plant without illustrating the processes carried on within. In such cases, a building would normally require some special architectural quality to justify listing.
MACHINERY	The special interest of some sites lies in the machinery. Some structures, such as Koepe winders or screening plants, are effectively machines in their own right and must survive relatively intact. In certain cases, such as the engine houses in the tin mining area of West Cornwall, the housing structures are emblematic of a major national industry and are listed even when structurally incomplete, and without their machinery. Generally speaking, where it is the machinery that makes a building special, the loss of this will reduce its eligibility for listing.
TECHNOLOGICAL INNOVATION	Some buildings may have been the site of the early use of important processes, techniques or factory systems (for instance, coke-based iron production, mechanised cotton spinning, steam power applied to pumping and so on). Technological significance may also reside in the building itself rather than the industrial process it housed, for instance, early fire-proofing or metal framing, virtuoso use of materials and so forth. The works of noteworthy millwrights or engineers will be of equal importance to major architects.
REBUILDING AND REPAIR	In assessments for listing, a high level of reconstruction is sometimes the basis for a decision not to list. With industrial buildings, partial rebuilding and repair is often related to the industrial process and provides evidence for technological change that may in itself be significant enough to warrant protection: alteration can thus have a positive value.

HISTORIC INTEREST	Where physical evidence of important elements of industrial history survives well, a high grade may be justified; where survival is less good, there may still be a case for designation, but judgment will be required. In some cases historical association with notable achievements may be sufficient to list: much will depend on the force of the historical claims, and the significance of the persons or products involved at the site in question. Considerable numbers of sites of industrial archaeological importance have been scheduled as ancient monuments. Past practice has generally been to schedule sites and remains, where monumentalised, and to list buildings. There is considerable overlap, however, and some dual designation. Our current approach is to consider what the appropriate designation response is, and consider how the site or structure is best managed. Dual designations will be reviewed as a priority. The following sections examine the special interest of specific industrial building types, splitting the category into three functional sub-sections: extraction; processing, finishing and assembly; and distribution and storage. It is particularly important when reading this section to bear in mind the overarching considerations outlined above.

Table 2-1: Listing selection guide for industrial structures (English-Heritage, 2011)

In Italy, there are not specific guidelines about the recognition and selection of industrial heritage but, however, the National catalogue of cultural heritage[79] is the main reference for the documentation of industrial heritage. The national cataloguing system is generally adopted also by organisation and research groups engaged in the subject, among which regional and local institutes and archives.

Moreover, among the initiatives for documentation of the architectural heritage, in Italy, there is a special institution for cataloguing contemporary architecture. The General Directorate for Contemporary Art and Architecture and Outskirts (DGAAP - *Direzione Generale Arte e Architettura contemporanee e Periferie urbane*), a body of the Ministry of Cultural Heritage, in fact, promotes and carries out research activities focused on the identification, documentation and cataloguing of the works of contemporary architecture of remarkable interest. These projects, aimed not only to the definition of protection strategies and tools, contribute to implement, in consultation with the ICCD, the national cataloguing system.

In particular, contemporary Italian architecture is being investigated with a National Census of Italian architecture of the late twentieth century: a mapping of architecture which was created to promote knowledge and valorisation and allows to identify the works of interest throughout the country through an interactive web platform. The

[79] The National catalogue of cultural heritage - for movable and immovable property - is managed by the Central Institute for Cataloguing and Documentation - *Istituto Centrale di Catalogazione e Documentazione* - ICCD, www.iccd.beniculturali.it.

catalogue, started in 2000, is constantly updated; the activities of recognition and documentation of the architectural heritage are carried on in collaboration with the Superintendences and institutes of MiBACT, even for the issue of the "statement of artistic interest" (Law 633/41). The research and survey are based on two different implementation methods: a general evaluation and a specific assessment organised on regional or local units.

The catalogue of cultural heritage, in the Italian context, is organised as a database that includes links and information about the various surveyed assets. The standard form for recording architectures (form A)[80].

The form synthesises the architectural, constructive and structural characteristics of the building with a brief description, geographical coordinates and the references to its history as well as its author (designer or builder).

In particular, as regards the industrial architectures, the instructions by the Ministry indicates a series of categories and definitions according to the functional-morphologic types of industrial building. The field OGT-Object gathers all the data for the identification of types and functions. The ICCD guide recommends an 'open vocabulary' for filling the form, such as 'Object Definition' or 'Object Qualification' according to several functional-morphologic types[81].

[80] Ministerial form for recording Architecture in the national General Catalogue of Cultural Heritage is the Form type A: definition Architecture, version 3.0 (2015), category: properties, sector: architectural and landscape assets, available online at www.iccd.beniculturali.it. It complies with the regulations issued by the Central Institute for Cataloguing and Documentation (ICCD), which also are defined in accordance with the International Standards of Archival Authority Records (ISAAR) www.icacds.org.uk.

[81] Catalogue standard available online at www.iccd.beniculturali.it/index.php?it/473/standard-catalografici. For the macro-category of industrial architecture/archaeology, the recommended functional-morphologic types are: shed (agricultural, industrial), power plant (electric, wind, hydroelectric, tidal, nuclear, thermal), drying kiln, factory (chemical, mechanical, metallurgical, oil production, iron and steel, textile), spinning mill, foundry, furnace, oil mill, forge, gasometer, waste incineration plant, waste treatment plant, warehouse, abattoir (slaughterhouse), workshop, glassware.

2.1.3 Degrees of protection for the architectural assets of the industrial heritage

The process of protecting the built environment (i.e. getting a heritage asset legally protected), include the listing of buildings valued because of their historical or architectural interest. In many countries, although only some heritage assets are judged to be important enough to have extra legal protection through designation/listing, buildings that are not formally listed but still evaluated as being of heritage interest are regarded as being a material consideration in the planning process. Additionally, various countries adopt a designation system based on different grade of listing and accordingly various 'degrees of protection'[82].

The approach of English Heritage for the industrial heritage, which represents an important international reference, is focused on both the diffusion of the knowledge and the designation for local planning, aimed to highlight also tourist and cultural potentials and to guide the forms of intervention. The buildings can be listed, according to the selection criteria, in three different 'grades', while the highest label is the registration on the national Tentative List for the nomination in the World Heritage List of UNESCO. The three types of listed status distinguish buildings of exceptional interest (Grade I), particularly important buildings of more than special interest (Grade II*), and buildings that are of special interest, warranting every effort to preserve them (Grade II). Listed buildings in danger of decay are listed on the 'Heritage at Risk' special register. Otherwise, the Department for Culture, Media and Sport (DCMS) works with Historic England - which has an interdisciplinary advisory role to the government, the local authorities and the public -, and other government departments to deliver the government policy on the protection to historic buildings and other heritage assets[83].

As regard designation and legal protection, the <u>industrial heritage of the last century</u> is generally less easy to evaluate (English-Heritage, 2011). In European countries, as observed in the English context, many of the more traditional industries (coal, iron and steel, but also the textile one) have steadily declined until there are relatively few sites left, while the huge complexes employing thousands of workers virtually disappeared

[82] Notable buildings and sites are usually inscribed on top-tier heritage lists, including the UNESCO World Heritage List, the Grade I listed buildings in UK, the National Historic Landmarks in the USA, the National Historic Sites in Canada (whc.unesco.org/en/list/, historicengland.org.uk/listing/the-list/, www.nps.gov/nhl/, www.historicplaces.ca).

[83] The legislation relevant to listing in UK includes the Planning (Listed Buildings and Conservation Areas) Act 1990 and successive regulations, as changes in the mainstream planning system as well as in the specialised heritage protection system are regularly being considered and progressed (the last one is Enterprise and Regulatory Reform Act 2013).

in the latter half of the twentieth century; a number of historic sites of this type were therefore cleared before a full evaluation could be made of their significance. Also other sectors have undergone similar cycles of contraction and concentration and relatively few buildings worthy of designation survive. Consequently, many industrial facilities from the last century have been converted in the last two decades.
The industrial heritage from this period includes internationally renown works from the early twentieth century, symbol of the new relationship between 'art and industry', the so-called 'by-pass modern factories', deriving from the concept of the 'daylight-factory' (long, low, and sleek modern buildings with large areas of glazing, in pleasant grassed settings) introduced from the USA, and innovative structures from international renown firms resulting from successive developments in factory design[84].
Beside masterpieces of industrial architecture[85], examples of protected building across Europe reveal a growing awareness of the issues of preservation of the twentieth century industrial assets[86].

In Italy, national laws and regulations discipline the recognition and protection of the cultural heritage, among which industrial heritage, which includes both historical buildings (from ancient spinning mills to settlements of the fascist era) and works of contemporary architecture (modern factories and contemporary industrial buildings).
The recognition of values of the industrial heritage concerns many architectural works, resulting mainly in various forms of protection by the Superintendence (*Soprintendenza Archeologia Belle Arti e Paesaggio* - SABAP), which consist in different conservation strategies: in some cases for partial decorative elements, in others for complex structures or entire settlements. Initiatives by the Superintendence have sometimes also started a positive collaboration within administrations, property owners and designers for the protection and redevelopment of sites (Maspoli, 2014).
On the other hand, neither specific national guidelines for the protection, nor a specific cataloguing system have been defined yet for the industrial heritage. The current protection strategies managed by the Superintendence concern, in fact, monumental elements more than other cultural signs of the industrial ages, with an approach based on recommendations rather than restrictions for the process of conservation, restoration and reuse.
Moreover, the interest of Superintendence is directed mainly to remarkable buildings / monuments of the industrial era and, therefore, preservation strategies for other

[84] An overview of the industrial architecture of the last century, with related examples, is included in the section "1914 to the present" of the Listing selection guide issued by English Heritage (see historicengland.org.uk/listing/selection-criteria/listing-selection/).

[85] Industrial heritage inscribed in the UNESCO World Heritage Sites list such as the Fagus Factory, the Van Nelle Factory and the Zollverein coal mine complex (see whc.unesco.org/en/list).

[86] Examples of listed (Grade II*) industrial buildings from the late twentieth century in the UK are the Hoover Factory by Wallis, Gilbert and Partners in London (1932-1935), the British Gas Research Station by Ryder and Yates in Killingworth (1967-1967) and the Renault Distribution Centre by Foster& Partners in Swindon(1983).

elements of the industrial heritage (minor buildings and smaller sites) are governed by local administrations (regional or municipal). As a consequence, intervention choices are often guided by the technical regulations of the town plans or local strategic plans, which refer to area planning strategies and hence implicate scarce uniformity and standardisation (Maspoli, 2014). The resulting lack of comparability of both regulations and documentation on industrial heritage implies also differences, for instance, in catalogues and recording systems and in the assessment of values related to architectural and historical elements.

The ordinary procedures of the Italian regulations are usually applied to industrial buildings inside urban settlements (town planning, i.e. through specific provisions for twentieth century architecture), while different strategies and specific programmes of public-private partnerships, since the '90s, have been applied for the conversion of larger industrial sites - as Urban Regeneration and Sustainable Development Programmes (*Programmi di Riqualificazione Urbana e Sviluppo Sostenibile del Territorio* - PRUSST) and Urban Regeneration Programmes (*Programmi Riqualificazione Urbana* - PRiU). Regeneration programmes, which might require long processes of consultation, approval and implementation, often resulted in conversion of brownfields, preventing soil consumption, but also revealing a limited conservation of the former industrial buildings. In addition, only a quite small part of the disused industrial heritage is protected by law (Maspoli, 2014).

In Italy, the main <u>legislative references related to the protection of industrial heritage</u> are contained in the Legislative Decree 42/2004, as regards the historic architectural assets, and the Law 633/1941, for contemporary architecture.

In detail, the Italian regulation distinguishes the cultural and landscape heritage in *Architectural assets* and *Landscape assets* and considers direct and indirect forms of protection.

The <u>architectural heritage</u> is considered in the Second part of the Code of Cultural Heritage and Landscape, as "Cultural Heritage", and in detail (article 10)[87]:

> 1. Cultural property consists in immovable and movable things belonging to the State, the Regions, other territorial government bodies, as well as any other public body and institution, and to private non-profit associations, which possess artistic, historical, archaeological or ethno- anthropological interest.
>
> 3. Cultural property shall also include the following, when the declaration provided for in article 13 has been made:
>
> a) immovable and movable things of particularly important artistic, historical, archaeological or ethno-anthropological interest, which belong to subjects other than those indicated in paragraph 1;
>
> d) immovable and movable things, to whomsoever they may belong, which are of particularly important interest because of their reference to political or military history, to the history of

[87] The translation of the original Italian document is by he UNESCO and available in the Cultural Heritage Laws Database, <u>www.unesco.org.</u>

> literature, art and culture in general, or as testimony to the identity and history of public, collective or religious institutions;
> 4. The things indicated in paragraph 1 and paragraph 3, letter a) include:
> h) mineral sites of historical or ethno-anthropological interest;
> i) ships and floats possessing artistic, historical or ethno-anthropological interest;
> j) types of rural architecture possessing historical or ethno-anthropological interest as testimony to the rural economy tradition.
> 5. Without prejudice to the provisions of articles 64 and 178, the things indicated in paragraph 1 and paragraph 3, letters a) and e), which are the work of living authors or which were not produced more than fifty years ago, are not subject to the Title.

However, whenever the premises and conditions occur (article 11, subparagraph 1, point e), the works of contemporary architecture of particular artistic value, can be considered cultural property, insofar as they are the object of specific provisions, as referred to in article 37 (economic incentives).

The Code explain in Section III the “Other forms of protection”, such as the provisions for <u>indirect protection</u> (article 45, subparagraph 1 and 2).

> 1. The Ministry shall have the power to prescribe the distances, measures and other regulations aimed at preventing that the integrity of immovable cultural property be put at risk, that their perspective or natural light be damaged or that conditions of the setting or decorous aspect of the buildings be altered.
> 2. The prescriptions referred to in paragraph 1, adopted and notified under articles 46 and 47, shall be immediately enforceable. The territorial government bodies concerned shall incorporate the same prescriptions into building regulations and urban planning instruments.

Also the <u>landscape protection</u> is governed according to the Code of Cultural Heritage and Landscape, in particular in the Third Part - “Landscape Assets”.
Landscape assets consist in “Buildings and areas of notable public interest*”* (art. 136), identified according to articles from 138 to 141, that are the “areas protected by law” (art. 142 such as coastal, marine and lacustrine territories, rivers and water courses, parks and natural reserves, territories covered by forests or woods, mountains etc.), and also building and areas protected by landscape plans (article 143 and 156).
In detail, according to article 136, e) “the complexes of immovable things which constitute a characteristic aspect having aesthetic and traditional value” are subject to the provisions for protection by virtue of their notable public interest.

Last but not least, as regards more recent industrial buildings (of living author or of less than 50 years), somewhat excluded from the above-mentioned regulation for the protection, contemporary architecture is currently protected by the Law on Copyright

(Law 633/41), provided that it is a creative and original work which has an "important artistic character"[88].
However this law is aimed to safeguard the author rather than the works and, in fact, it grants (only) the author (designer) the right to decide about modifications and adaptations of its work (such as in case of restoration, renovation of reuse) or to refuse alterations which might compromise its original character.
As for the architecture of the late twentieth century, for example, the Ministry has defined specific requirements and essential characteristics - of historical critical nature, sufficiently well documented from literature sources - to express a first assessment of the artistic character of the works (criteria also used for the catalogue).

According to this legislative framework, the activities of protection, preservation and restoration of the historic and contemporary industrial heritage begin by the prior approval of the cultural interest or important artistic character of the works, to be subjected to particular forms of attention and provisions. The identification of such works can occur through the declaration of cultural interest and the application of restrictions in accordance with art. 10 paragraph 3 letter d) of the Code of Cultural Heritage and Landscape, or the declaration of an important artistic character within the meaning of the Law on Copyright. Special safeguards and protection strategies can be defined for the selected works, in agreement with local authorities, and institutions can disburse funding and economic incentives for their maintenance and restoration. For instance, for the contemporary architectural works declared of 'important artistic character' (Code of Cultural Heritage, article 37 paragraph 4), a ministerial economic grant can be requested in case of restoration.

As already mentioned, the protection of industrial heritage works could take place also through the planning instruments provided at regional and municipal level. In recent decades, in fact, the Regional Territorial Plans (*Piano Territoriale Regionale* - PTR) and Landscape Plans (*Piano Paesaggistico Regionale*), in various regions, have provided specific sections dedicated to cultural heritage and in particular to the theme of industrial heritage.
The Territorial Plan of Lombardy region, for instance, in the *Repertoires of industrial archaeology* section, identifies a number of industrial settlements relevant for the history of the development of the territory (e.g. Dalmine site in Bergamo, Crespi d'Adda settlement), as well as other industrial buildings identified as cultural properties of particular landscape importance[89].
The theme of industrial archaeology has assumed, for example, particular relevance also in the Veneto region, in the drafting of the Coordination Regional Territorial Plan

[88] As explained above, the body in charge of the documentation and protection of contemporary architecture in Italy is the DGAAP, www.aap.beniculturali.it/dirittoautore.html.

[89] The "Repertoires of industrial archaeology" document is available online at www.territorio.regione.lombardia.it.

(2009) and the 2013 version. Also in this case, in large portions of the region, an industrial heritage with special characters is present and characterised by the link with the rural world, the presence of many relics of early industrialisation including individual buildings (mills, power plants, hydroelectric power plants, pumping plants, kilns, sawmills, mines, mills, etc.), or infrastructure networks (railways, tramways, aqueducts, etc.) and articulated settlements (neighbourhoods, workers' villages and city). An initial list, meant to be implemented in the future, was drafted and published in the document for landscape planning as a starting point to understand, preserve and enhance the industrial heritage, yet often underestimated. The catalogues includes some of the most significant industrial archaeology building and sites in Veneto, and constitutes a partial variant with attribution of landscape value to the selected building[90].

In the Friuli Venezia Giulia region, landscape assets protected under art. 136 of Code are about 50 (to which must be added 25 natural caves), while those of greater extension - today hardly quantifiable in their area - are the areas protected under art. 142 of the Code, among which the regional natural parks as well as the regional and state natural reserves.

With the drafting of the new Regional Landscape Plan, between 2015 and 2016, a new reconnaissance and cataloguing process has been started, searching for assets with landscape value, including those belonging to the macro category of industrial archaeology. The plan provides, in fact, the recognition of landscape components through two basic levels of analysis: a first, at general scale, refers to the landscape areas (under art. 135); a second, at detail scale, aimed at the recognition of landscape assets (under art. 134), which includes building and areas declared of significant public interest, areas protected by law and additional buildings and areas identified in the plan due to their landscape value[91].

This second layer for 'landscape assets', being drafted, implies a phase of reconnaissance and delimitation of areas and buildings protected and will conclude with the preparation of a map of the landscape assets and the determination of use requirements and prescription to ensure the preservation and valorisation of them, including the macro category of industrial archaeological heritage. In addition, the website dedicated to the participatory planning, and in particular the sections dedicated to reporting and mapping the landscape assets[92], highlight the growing

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[90] The selection of building was included in the Annex B3 an illustrated catalogue of works of industrial archaeology (4.6.) and twentieth century architecture (4.7); the list is based on a homonymous research published in 1990, and complemented by the latest studies for the area of Vicenza (www.regione.veneto.it/web/cultura/archeologia-industriale). Industrial archaeology is governed by Article 60, paragraph 3, letter. e) of the Technical Norms of the plan (www.regione.veneto.it/web/ptrc/ptra-variante-adottata-2013).

[91] A dedicated webpage on the landscape plan is available on the website of the Region Friuli Venezia Giulia (www.regione.fvg.it/rafvg/cms/RAFVG/ambiente-territorio/tutela-ambiente-gestione-risorse-naturali/FOGLIA200/FOGLIA2/).

[92] The web-gis on partecipatory planning for the Regional Landscape Plan is available online at partecipazionepprfvg.gis3w.it.

public attention to the issue of industrial heritage. There are, in fact, many suggestion about manufacturing contexts in the region: both industrial archaeology in a state of neglect, in need of protection and regeneration, and modern buildings and production facilities subject of recent neglect and decay.
This wide and articulated regulatory background on the protection of industrial heritage often resulted in substantial difficulties in promoting concrete initiatives for the preservation and valorisation of industrial assets. The long process for the legal protection act, also due to the lack of coordination within state and local institutions and stakeholders, might obstacle necessary actions for heritage in danger. Such is the case of many industrial properties subject to ruin or otherwise to change of ownership and intended use.

Furthermore, the issues about the protection of contemporary architecture remain somewhat unsolved due to the 'time barrier' established in the age criteria defined by the regulation on cultural heritage, which exclude works from less than 50 years or designed by a living author[93]. On the one hand, these criteria, however adopted also by many other countries, represented the major impede to obtain the legal protection of modern industrial architecture, considering that the spread of such building in Italy has consistently happened in the late twentieth century, with the major developments of the industrial sector and the construction of notable factories.
Besides, on the other hand, the legal protection under the Law on Copyright, proved to be not really appropriate for architectural heritage, being based on private initiatives and interests. Moreover, even the listing of building in the *Catalogue of Italian architecture of the late twentieth century* may not always be reflected in appropriate forms of protection. Often the DGAAP - which might also issue the declaration of artistic interest - demand to local and municipal authorities the discretion in including the selected building in local planning provisions.
In this sense, in the case of modern heritage, the legal protection measures provided by the Italian law often proved to be little useful. Even tough a contemporary building would obtain the status of listed building, the legal protection often do not suffice in the preservation of memories and values (i.e. preventing demolition but not substantial modification of the interior spaces). In this respect, the recognition of interest (the declaration of cultural interest) should be understood as a preliminary action within a comprehensive approach that envisages a system of continuous maintenance of the architectural assets.

Nevertheless, several remarkable works of modern architecture in Italy are now protected by law: among the youngest ones the bridge on Basento (Sergio Musmeci, 1971-1976) and the Alfa Romeo Museum (Vito and Gustavo Latis, 1976); a remarkable piece of industrial architecture, the Cartiera Burgo (Nervi, 1961-1964)

[93] The issues of legal protection measure for contemporary architectural heritage are widely discussed in (Carughi, 2012).

have recently obtained the status of 'listed' building[94]; lately this year, also a comprehensive protection act has been proposed for the Olivetti factory in Pozzuoli (Cosenza, 1954-1970) - currently the protection measures involved only the exterior[95]. Additionally, recent debate on the protection of industrial heritage has drawn attention to the concept of 'serial heritage', bringing up as examples the works of Pier Luigi Nervi, particularly relevant as regards the focus of this study[96],

[94]The protection status of the Cartiera Burgo in Mantova was mentioned in chapter 1.

[95] Updates on recent initiatives and legal protection measure for relevant works of modern architecture in Italy are issued by Docomomo Italia, for instance through the various calls for protection for specific cases of heritage in danger www.docomomoitalia.it/patrimonio-a-rischio.

[96] The concept of 'serial heritage', however assumed by the UNESCO since the '80s, has been re-proposed by the president of Docomomo Italy as a principle to protect and ensure the necessary attention to architecture of the twentieth century. The cited works by Pier Luigi Nervi includes the many arch structures and vaulted roofs, which are not currently protected, and could benefit from an overall protection and valorisation strategy according to the concept of 'serial properties/sites' (Carughi, 2016).

2.1.4 Industrial heritage in a regional context: the case-study of the Friuli Venezia Giulia region

In light of the above considerations, the issues related to the protection of industrial heritage appear articulated and multidisciplinary. The contextualization of the theme in the region has been an interesting opportunity to study the more specific and practical aspects on protection (legal protection measures and planning instruments) and intervention for the works of industrial architecture[97].

The study was carried out with particular reference to the activities of the Superintendence regarding the new Regional Landscape Plan (in progress in 2016).

The data already collected in the various regional and national databases[98] have been analysed and compared in order to produce a synthetic catalogue of industrial architecture in the region and to identify significant works, such as building already under protection or worthy of designation. In detail, the documentary material held by the Superintendence and the Regional administration, such as the historical report attached to the ministerial decrees for protection and the records of the Regional Catalogue of Cultural Heritage, has allowed a first evaluation of the industrial assets in the area. The collected data were then standardised and ordered in the catalogue, according to the several significant categories of designated industrial buildings. The assets so far surveyed in the Region include factory types ranging from the large industrial complexes with the workers' villages, to the oldest factories linked to the water system, the textile factories, such as spinning mills and cotton mills, the furnaces, the other types of factories and power plants.

Given the large amount of assets catalogued (about 700), the critical review of the data collected has led to the selection of the most significant buildings for each type, with attention to architectural and landscape value, taking into account the most relevant studies and publications on the topic and the protection measures already in place. A synthetic documentation fiche has been drafted to describe main features, architectural and landscape value and protection reasons (whether already in place or not) for the selected buildings.

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[97] This phase of the study was carried out during a period of traineeship at SABAP FVG - *Soprintendenza Belle Arti e Paesaggio del Friuli Venezia Giulia*, *Ufficio staccato di Udine* (Superintendence), under the agreement between the University of Udine and the Superintendence (Convenzione n.2015.080.TF.LP, 16th March 2015) and the formative programme (2015.080.TF.LP/009.PL); dates: from 1st July 2016 to 31st July 2016; supervisors: prof. Anna Frangipane and prof. Giovanni La Varra, for the University of Udine, and arch. Stefania Casucci, for SABAP FVG.

[98] The records of the Regional Catalogue of Cultural Heritage - *Catalogo Regionale del Patrimonio Culturale* of Friuli Venezia Giulia are available online at www.ipac.regione.fvg.it; the national database of protected assets is available online at http://vincoliinrete.beniculturali.it.

Industrial architecture in the regional catalogue of cultural heritage: amount, types and values

The size and condition of the industrial heritage in the region Friuli Venezia Giulia is the results of the industrial development which has brought about modern production processes in a territory still deeply related to agriculture and farming.
The traces of the early development are found in proto-industrial buildings such as flour mills, spinning mills and steel mills, which are a constant and widespread presence linked to the water system in the region. Large textile factories date back to the successive period of industrial development of the territory, for example the plants in Pordenone, in the Udine the area, as well as those in Gorizia and Trieste.
From World War I, for economic and certainly infrastructural reasons, there has been a substantial slowdown in the industrial sector growth, but there are still notable examples of industrial architecture of the early twentieth century, as well as large industrial complex of the fascist era.
The '50s and '60s onwards, the development of industry implicated the formation of a number of new production areas in which notable architectural works can be found.
Taking into account that industrial architecture not only includes buildings, but also machines, archives, industrial processes and workers' villages, it is clear that the industrial heritage of the region is substantial and varied. It is a heritage that is often left abandoned and not fully understood, so that despite the efforts of private and public organisations, such as the cataloguing centre and other initiatives for documentation[99], many works are still little known and not protected.
However, there are also good examples of restoration and renovation, as in the case of the former hydroelectric power station Pitter in Malnisio, the former textile drying in Tricesimo, the former textile mill Pividori in Tarcento, or the projects currently under way to for the ‘Porto Vecchio’ (old harbour) of Trieste[100].

Since the '70s, the Centre for cataloguing and training of the Regional Research Institute for Cultural Heritage of Friuli Venezia Giulia conducts research, training and documentation activities and promote the awareness, the active preservation and the valorisation of the cultural and landscape assets of the region. A significant outcome of these activities has been the creation of the Regional Catalogue of Cultural Heritage, consisting of a substantial collection of digital catalogue-records about the

[99] Relevant activities of documentation and valorisation of the local industrial heritage are carried out, for instance, for the city of Torviscosa, Udine province (www.cid-torviscosa.it), for the mining site of Raibl, near Tarvisio, Udine province (www.minieradiraibl.it).

[100] Details on the restoration of the hydroelectric power station in Malnisio, Pordenone province, and the new museum are included in the dedicated webpages www.taarchitettura.com/schede_lavori/malnisio/malnisio.html. More information on the restoration of buildings in the ‘Porto Vecchio’ of Trieste are presented on the website (portovecchio.comune.trieste.it/il-porto-vecchio-di-trieste/edifici-restaurati/).

architectural and landscape assets of the Friuli Venezia Giulia region. There are about 10,000 records, belonging to 6 groups of cultural assets corresponding to specific types of forms: Architectures (A), Industrial Archaeologies (AI), Historical Places (LOS), Historical Settlement (IS), Parks and Gardens (PG), and Trees (ALB).
The first catalogue records have been drafted since 1971 on paper, then replaced by digital versions, together with the new content, in a database available online since 1999 and later transformed in the Regional Information System for Cultural Heritage now in use. The catalogue of architectural and landscape assets is continuously updated, usually through thematic campaigns and shared cataloguing activities - as recently happened with "Parks and Gardens" or "Bell Towers".
The Industrial Archaeology section is, in fact, the result of numerous cataloguing campaigns that, over the years and involving different stakeholders, concerned specific issues (i.e. census by types of mills, furnaces) or certain geographical areas (i.e. the recent update of the architectural heritage in the area of Torviscosa). Currently the section includes 791 works catalogued (between existing and not), of which only 333 properly geo-referenced and displayed in a web-gis (under update).
There are numerous types surveyed: from factories processing the raw material, such as cotton mills, furnaces, workshops, foundries, paper mills, distilleries, to works such as dams, bridges, aqueducts, and even power stations, stations and railway tracks as well as homes and service structures for industrial activities, including offices and residential buildings, warehouses and silos[101].

The scheme of the standard form for Architectures (A) in the catalogue complies with the regulations issued by the Central Institute for Cataloguing and Documentation. The remaining types of forms have been created for regional documentation needs, respecting the scheme of the ministerial form; the form for Industrial Archaeologies, set up in 2001, is therefore a derivative version of the ministerial form.

[101] The architectural and landscape assets of the catalogue can be viewed through a web-GIS platform (servizi.informcity.it/gis/cake/icpro_sitbec/), on different base maps, even by setting specific spatial or typological search criteria; alternatively, more detailed searches are possible by accessing the catalogue on the web portal (www.ipac.regione.fvg.it). In both cases, from the search results the complete profiles of the catalogue can be accessed, displaying details about the selected building and iconographic material, according to the ICCD-AI form.

The selection of buildings of relevant architectural and landscape quality

The survey in the regional area, thanks to the data on the regional catalogue (section industrial archaeology) has led to the production of a synthetic catalogue of industrial building including the selection of significant works already protected by law or worth protection.

The full collection includes about 500 industrial buildings, from different epochs, classified by their functional types in seven main categories: industrial complexes, mills, smithy and foundry, furnaces, textile factories, other factories, water infrastructures and plants. The catalogue includes information about the current condition and protection of the building/sites, and in particular if the industrial site/building is suggested for protection measures, or if it is already protected by law.

The analysis reveals the presence, in the region, of several remarkable industrial complex with their workers' villages, such the industrial site in Straccis (Gorizia), the shipyard site in Monfalcone (Gorizia) and Trieste, the chemical plant in Monfalcone (Gorizia), the old harbour in Trieste, the mining site in Raibl - Cave dal Predil (Udine) and the entire city of Torviscosa (Udine).

Furthermore, the area is characterised by the presence of a great number of proto-industrial facilities, especially water mills (146), such as flourmills, spinning mills and iron-mills[102]. Several of them are now protected by Law (42/2004), such as the ones in Aviano, Bannia, Polcenigo in the Pordenone province, and Cividale, Rigolato, Gemona and Mereto in the Udine province, while many others, although less known, are worth preservation.

The survey highlights also a quite relevant presence (24) of smithies, forges, iron foundries and steel mills, from different epochs. Remarkable sites related to ironworks, which are currently protected, are however quite recent: the Weissenfels industrial site in Tarvisio (Udine) and the Safau Steel plant in Udine.

A relevant amount of textile factory was acknowledged in the region due to a long tradition, which started with the breeding of silkworms and silk processing[103]. The most notable buildings, now protected, are the spinning mills in Tricesimo, Chions, Spilimbergo and Bertiolo, but also other remarkable and well-know examples are the ones in Cividale, Dignano, Carpacco, and Tarcento (Ripari and Pividori), all in the Udine province. The area of Pordenone is characterised by the presence of three outstanding works of industrial architecture: the abandoned cotton mills Amman, Olcese and Rorai Grande. Other two remarkable deserted cotton mills are located in Gorizia (Carde Cotone) and Ronchi dei Legionari (Vermegliano).

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[102] The presence of mills in the region is widely reported and discussed in publications regarding specific geographical areas (Penzi, 1989; Colonnello *et al.*, 2002; Mattaloni, 2010; Duca, 2011).

[103] Textile factories and workshops in the region are presented in various publications and discussed in detail in several studies (Bartolini, 1974; Valcovich and Croatto, 1994; Bof, 2001).

Many furnaces, in different conservation, could be found across the Region[104]: from about 50 reported in the past, now only a few left, such as the limekilns in Aviano, Montereale, Morsano, Rubignacco, Qualso, Remugnano, Remanzacco, Torviscosa and Udine.

However, also other industrial activities left their physical remains, now protected, across the territory: tobacco drying kilns (in Ronchi del Legionari and San Canzian d'Isonzo), breweries (in Pordenone and Trieste), and other factories such as the Amideria Chiozza (for the processing of rice starch, in Ruda), the mechanical workshop Holt (Trieste), the chocolate factory Lejet (Trieste), the paper factory Burgo (Tolmezzo - not protected) and the mining site of Raibl (Cave del Predil, Tarvisio). There are also many buildings for the storage and trade of goods such as the Municipal Slaughterhouse and refrigerating building (Udine), the Municipal Market and Fish Market (Trieste), the Silos (Trieste), and the Gasometer (Trieste).

A series of outstanding examples of the link within the water system and the industrial development of the territory are acknowledge in the region[105]: draining pump buildings and hydraulics works built for the land reclamations in the first decades of the twentieth century (three water-scooping plant in Aquileia, a plant with canals in Sagrado), water towers (Gorizia, Aurisina, Fossalon) and hydroelectric plants (Malnisio, Isola Morosini).

Finally, the industrial heritage of the region is characterised also by notable industrial building from the late twentieth century (F. 2-9 - F. 2-15)[106], such as the works by Pietro Zanini (IFAB plant in Palmanova, 1963), Gino Valle (Zanuzzi Offices and the various plants in Porcia and Pordenone, 1959-1969; printing workshop Chiesa in Udine, Geatti warehouse and showroom in Terenzano, 1974 and others), and Angelo Mangiarotti (Snaidero offices and plant in Maiano, 1978).

A number of these notable industrial buildings from the late twentieth century are characterised by a large use of concrete and prefabrication, and some of them in particular were made with the use of precast concrete panels.

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[104] The relevant development of furnaces in the area is reported by Buora and Ribezzi (1987); Piccinno (2001).

[105] The theme of land reclamation and works related to widely discussed by local studies (De Piero, 1975; Duca and Cosma, 2005; Frangipane, 2011) as well as the link within electric power, power plants, infrastructures and landscape (Zin, 1988; Pavia, 1998).

[106] Modern industrial buildings are not often included in the Regional Catalogue of Cultural heritage but, however, they are cited in many guides on local architecture (Bigatton, 1995; Pozzetto, 1996; Baccichet *et al.*, 2016).

F. 2-1: Raibl mining site, Cave del Predil (ipac)

F. 2-2: SNIA factory in Torviscosa (author, 2015)

F. 2-3: spinning mill in Tarcento (ipac, 2016)

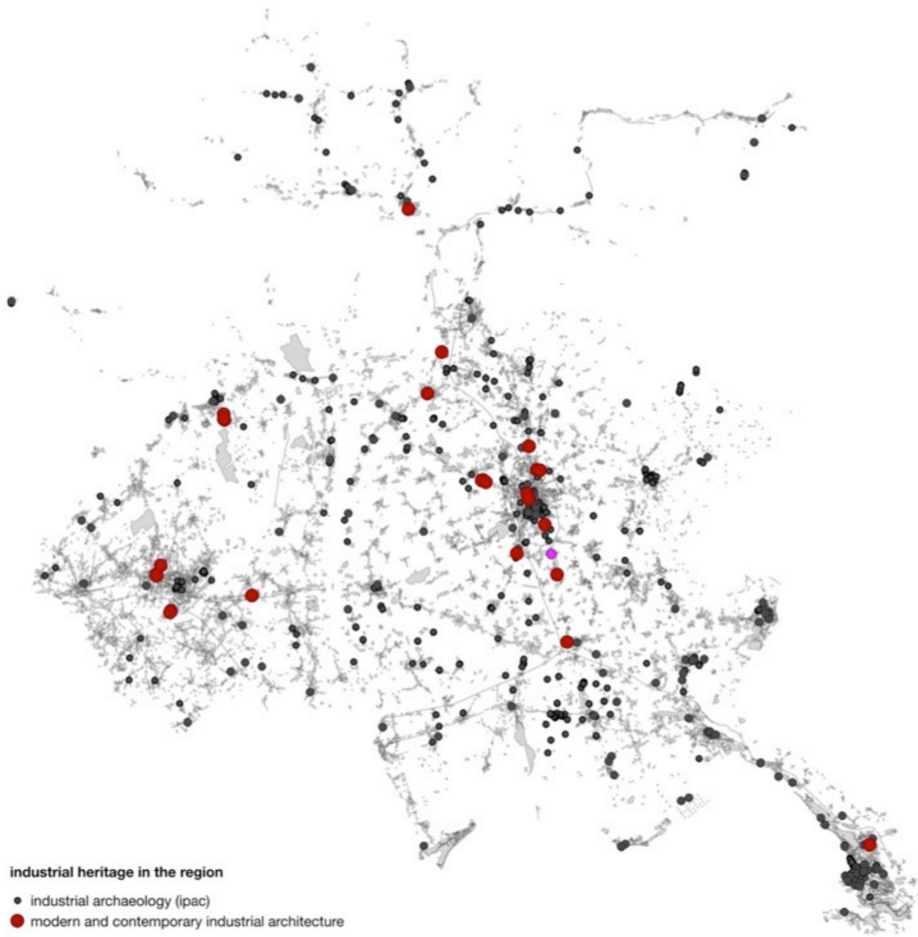
F. 2-4: spinning mill in Dignano (ipac, 2016)

F. 2-5: cotton mill in Torre, Pordenone (ipac, 2016)

F. 2-6: cotton mill Amman, Pordenone (ipac, 2016)

F. 2-7: water tower in Fossalon (author, 2014)

F. 2-8: hydroelectric plant 'Isola Morosini' (ipac)



F. 2-9: map of industrial heritage in the Friuli Venezia Giulia region, industrial archaeology assets and modern and contemporary industrial buildings; classification and integration of data from ipac and SABAP (author, 2016)


F. 2-10: Snaidero factory, Majano, A. Mangiarotti (2015)

F. 2-11: Geatti factory, Terenzano, G. Valle (2015)


F. 2-12: Textile factory Riviera, E. Mattioni (author, 2014)


F. 2-13: Chiesa printing factory, G. Valle (author, 2014)


F. 2-14: factory in Maniago, FACEP (author, 2015)


F. 2-15: former Zanussi buildings in Maniago (author, 2015)

2.2 Performance degradation of industrial buildings

The discussion about industrial heritage and the rising interest in the refurbishment of industrial sites concerns also the analysis of the specific issue of tangible material features of industrial buildings. In this sense, in a performance perspective, the problems of structural and seismic behaviour, material decay, functional obsolescence and upgrade are discussed as related to the definition of the specific frailty of prefabricated building and precast concrete elements.

The most relevant issue regarding prefabricated industrial building is their seismic vulnerability, highlighted also by the recent earthquakes in the country, which pointed out the critical aspects related to the very nature of this building type. The difficulties in fulfilling safety requirements, particularly from the seismic point of view, depend also on precast concrete panels, even if non-structural elements, due to connection failures, collapses or incorrect interactions with the structural system (paragraph 2.2.1).

On the other hand, over the last few decades, architectural conservation has faced modern architecture and the contemporary built-environment focusing on the problem of the material decay and weathering and therefore the issues of concrete deterioration. The topic is widely investigated in literature, referring to the growing awareness and concern about possible intervention approaches for fair-face concrete and special components such as precast concrete panels (paragraph 2.2.2).

Additionally, the performance of the building envelope is and will continue to be of major concern, as industrial buildings are often characterised by their inability to fulfil current requirements for energy efficiency and sustainability. The problem of thermal performance, as highlighted by many studies, is particularly relevant as largely dependent on the precast concrete walls (paragraph 2.2.3).

However, besides the performance degradation, the growing concern about sustainability puts in question also the issue of end of life disposal, particularly of under-utilised or abandoned industrial buildings, for which the best solution could be demolition. In this sense recent studies have brought about considerations concerning both the cost of dismantling and recycling, and the evaluation of the utility of void spaces, questioning if the recent 're-naturalisation' approach is a valid choice, also from a financial perspective (Maspoli, 2014; Marini and De Matteis, 2014). Other critical issues relate to the functional obsolescence of industrial buildings, particularly the transition from the Fordist-Taylorist concept of spaces for work to an approach oriented on liveability of the spaces and buildings, for both worker and customer satisfaction (from the comfort of indoor spaces to a company's brand image). Taking into account these premises, the issue of reuse and transformation of industrial building is discussed in the next chapter.

2.2.1 Performance degradation of industrial buildings: structural issues

In 2012, following the earthquake in the Emilia area, Marco Biraghi introduced an interesting perspective on the nature of prefabricated industrial buildings: the similarities and the contrasts that mark the transition 'from the shed to the warehouse' become, in fact, clear with the earthquake. These buildings - also as the result of a utilitarian logic that led to the spread of a typical neutral container (emblem and final product of the industrial culture) - do not show any lightness and neutrality, and, indeed, the effects of their collapse are quite different from those of the fall of even a large shed. Apart from the name, with the latter they maintain one (not negligible) common feature: the absence or minimisation of foundations (Biraghi, 2012).
Also during past seismic events, conventional reinforced concrete precast buildings have already suffered extensive damage, revealing their poor performance (2009, L'Aquila). The earthquakes, in fact, highlighted the serious problems related to both the large spread (in the Italian territory) and the very conception of this building type. In this regard, since 2005, research at national level, thanks to the activities of the group ReLUIS [107], has focused on issues related to the seismic behaviour of prefabricated structures. Research activities led, moreover, to the publication of several technical documents about prefabricated structures (Mandelli Contegni *et al.*, 2007; Mandelli Contegni *et al.*, 2008). Furthermore, detailed field observations on a relevant number of industrial precast buildings was carried out just after the seismic sequence, outlining the main vulnerabilities of these structure also through examination of case-studies (Belleri *et al.*, 2015).
Structural vulnerability of prefabricated structures is linked to building types and the elements they comprise, and concurrently to their epoch of construction. Studies in the Italian context have therefore focused on the main vulnerabilities of one-storey precast concrete structures, which are the prevalent type in the area and are not designed and detailed for seismic loads. Even though each building type (vaulted structures, concrete skeleton, bearing panels) might reveal specific frailties and mechanism, the key role of the proper choice, design and detailing of the connection system is well-established in literature. In general, in precast r.c. structures, connections were designed neglecting seismic loads[108]. The premature failure of connections might cause the collapse of part of the buildings, primarily the roof, due to the loss of support of beam elements. Additionally, the higher flexibility of these type

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[107] ReLUIS *Rete dei Laboratori Universitari di Ingegneria Sismica* - the Network of University Laboratories of Seismic Engineering; research activities into prefabricate structures were carried out within the research programme 2005/08-DPC/RELUIS *Linea di ricerca 2: Valutazione e riduzione della vulnerabilità degli edifici esistenti in c.a.*

[108] Generally simply supported connections (beam-to-joist and beam-to-column) were primarily constituted by vertical steel dowels or solely relying on shear friction, with or without neoprene pads.

of buildings (if compared to traditional r.c. structures, according to both higher interstorey height and cantilevered static schemes) causes a larger seismic displacement demand and may also result in displacement incompatibility between structural and non-structural elements, such as precast concrete cladding panels, causing their connection failure.

As another frequent failure typology observed during the seismic events was the collapse of the cladding panels, the discussion in the field has considered also the safety requirements and specific mechanism involving precast wall and cladding elements of industrial buildings. As regards precast concrete panels, latest studies have defined several key points[109].

Precast concrete panels are, in most cases, non-structural elements which, connected to the bearing structure, constitutes a cladding. They can be laying horizontally or vertically, with different solution for the integration of windows and doors. Vertical panels could be embedded at the base - solution no longer in use -, or simply placed against the structure and fixed at the top. Horizontal panels could be placed externally to the structure or embedded within the pillars in dedicated slots. From a mechanical point of view, precast concrete wall panels were meant to grant resistance to collision and to absorb wind loads and transfer them to the supporting structure; they might possibly serve as a retaining wall for the underground parts.

The panels are commonly connected to the main structure (beams, pillars) with specific mechanical elements, the metal inserts, whose properties were defined by regulation (strength, ductility, durability)[110]. However, the connection system between the cladding panels and the structure, designed neglecting seismic loads, is a real critical point of prefabricated buildings, as evidenced by the recent earthquakes and reaffirmed by subsequent studies (Re Cecconi F., 2009; Mordà, 2014; Belleri *et al.*, 2015). Considering the mass of these prefabricated elements (in the order of tons), it is clear the role and the importance of the connections also in terms of safety. In detail, the system to fasten the panels to the structures depends on the arrangement of the panel (horizontal or vertical laying) and in general must ensure the restraint of the vertical panel (support), the restraint of the horizontal panel (anchor), and the connection within the panels (anchor)[111].

However, the design approach in the past has always been oriented to consider the panels as non-structural elements and, consequently, to size connections only for their self-weight and perhaps the wind action. During dynamic actions like the seismic one, however, the connection systems can not provide effective isolation of the panels

[109] A comprehensive review on the topic, referred to recent studies on seismic vulnerability of prefabricated industrial buildings in Italy is presented by Mordà (2014).

[110] "Istruzioni per il progetto, l'esecuzione ed il controllo delle strutture prefabbricate in calcestruzzo- CNR 10025/98", recommendations by CNR in 1998.

[111] Types of connection used in industrial building are widely illustrated in (Mandelli Contegni *et al.*, 2007) The distinction between the two types of connection as support or anchorage systems according to their function is explained in (Mordà, 2014).

from the structure. Thus the interaction of the panels with the structural system, involving additional and unplanned stresses to the connections, results another critical element of the system.

In general, the panels might contribute differently (in term of weights) according to their laying (vertical or horizontal), and also act at the level of overall stiffness of the building, altering the dynamic behaviour.

In detail, usually the panels are classified in two types according to their 'isostatic' or 'collaborating' behaviour: panels not interfering with the global behaviour of the building (able to resist, together with the connections, the gravitational loads and the displacements imposed by the earthquake), defined as 'isostatic'; panels that interact with the structure and alter the structural response of the building, defined as 'collaborating'.

In the first case, the panel-structure connection system must not have too much stiffness that affect the structural response and, indeed, must be able to accommodate relative displacements - in particular the large horizontal displacements in the plane of the panels, up to tens of centimetres -.

In the second case, the collaborating panels, increasing the lateral stiffness of the building, assume the role of bracings and must be considered (and designed), along with their connections, as structural elements.

According to the types of precast concrete wall panels, the main problems related to seismic events were recognised as the danger of collapse of the panels, the alteration of the dynamic response of the building, the creation of particular pillar stress situations (pillar complete collapse) in case of ribbon windows.

About retrofit solutions, recent literature reaffirms the need of rationally conceived mechanical connectors to properly allow for displacement demand rather than try to make them work for unfeasible strain and load levels (Belleri *et al.*, 2015).

As for the interventions on the elements of the building envelope, the requirements for the cladding panels and their connections are basically to prevent the collapse of the panel, to allow, if possible, the relative displacement of structure and panels, especially in the plane of the panel, in order to avoid collaboration between non-structural components and load-bearing structure, and, in any case, to maintain the existing static scheme[112]. Recent studies[113] propose two main categories of action (for horizontal or vertical panes), which include the use of appropriate connections and the addition of safety cables to prevent the collapse of the element.

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[112] Document by Reluis, Gruppo di Lavoro Agibilità Sismica dei Capannoni Industriali, *Linee di indirizzo per interventi locali e globali su edifici industriali monopiano non progettati con criteri antisismici*. 2012.

[113] For vertical panels: the collapse can be prevented through the use of brackets fixed to the beam and the panel to the upper two corners and insertion of anti-drop cables fixed to cross member and the panel to the upper two attacks. For horizontal panels: the collapse can be prevented through the use of brackets anchored to the pillars and the four edges and fall cables fixed to the four corners, as depicted in drawings presented in (Mordà, 2014).

2.2.2 Performance degradation of industrial buildings: material issues

Over the last few decades, architectural conservation has faced modern architecture and the contemporary built-environment. The problem of concrete decay in modern architecture is widely investigated in literature (Macdonald, 2003; Bruschi *et al.*, 2005; Canziani, 2009; Di Biase, 2009; Macchi *et al.*, 2010; Graf and Delemontey, 2012; Jester, 2014; Graf and Delemontey, 2015; Coppola and Buoso, 2015), also referring to the growing awareness and concern about possible intervention approaches, such as the question of repair or replace (Fixler, 2008; Jester and Fixler, 2011). The issue results central, as industrial architecture in Italy has largely concentrated upon concrete construction techniques, from the large engineering constructions to the widespread prefabricated buildings. Additionally, these building were often realised following a quantitative rather than qualitative standard, and concurrently they are exposed to environmental condition more aggressive than usual. Even though the problem of the material decay and weathering is mainly referred to early concrete architecture and pioneering components (structures and panels), also the industrial architecture of the recent past - such as prefabricated buildings - is a vulnerable heritage. The loss of performance was in fact sometimes exacerbated by the environmental pollution of industrial plants, due to the presence of caustic chemicals, sometimes related to the manufacturing activities taking place in the building. In addition, the decommissioning of sites and the subsequent abandonment of building or, otherwise, the poor maintenance and neglect, accelerate the degradation process, frequently leading to the cancellation of the physical traces of this heritage.

In this sense, reflections and considerations regarding the material aspects of the conservation are relevant for prefabricated industrial architecture too. The state of knowledge regarding the deterioration mechanisms that affect reinforced concrete generally, and precast wall panels specifically, as well as the strategies currently utilised in their preservation is synthesised in the following paragraphs. Although reporting well-known aspects, this necessary synthesis is presented to be thorough and to form a useful background, which is accompanied by a brief reportage of some significant cases of degradation and repair of concrete directly observed in prefabricated industrial buildings throughout the country.

Concrete deterioration: general pathologies and vulnerabilities of precast concrete panels

Like architectural products were standardised as a quite natural step in the growth and quality of the field, since the origin of precast concrete materials and processes were predetermined based upon scientific study and experimentation. Concurrently, the issues of concrete weatherability and deterioration had arisen, leading progressively to more durable and appropriate solution in terms of material features and component design. The advancements in scientific testing at the turn of the twentieth century were an important step in this development, allowing scientists and constructors to improve the quality of concrete and introduce design guidelines. Then, especially in the '50s and '60s, a rapid development in precast components, such as panels, both as structural and as cladding elements, promoted the definition of more specific quality standard and recommendations[114].

Although reinforced concrete could be an extremely durable material - having become an attractive building material especially for the industrial and infrastructural sectors - the porous nature of concrete, the vulnerability of the steel reinforcement, and the tenuous compatibility between the two inevitably lead to the deterioration.
However, although the deterioration mechanisms responsible for concrete degradation stem, even today, from the same factors - besides exposure and site-specific phenomena - often the causes do not proceed from mix and design specification but from limited knowledge in the design of proper reinforcement, joints and sealing, which were still in their initial stages of development in the past (Cellini, 2008). This is why, for instance, moisture problems in early concrete panels often depend on the jointing system (design of joints) and the provisions for adequate water drainage.

As a reinforced concrete assembly, precast concrete panels are subject to the pathologies that affect general reinforced concrete.
A long tradition in concrete technology has shown how concrete deterioration might depend on both intrinsic and external factors. In this sense, the use of exposed (fair-face) concrete, which is - and was - very common for industrial building, implies the reduction of building yard works but also specific qualities, as durability and aesthetic requirements (colour, texture). Furthermore, technology for exposed concrete implies

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[114] These advancements in concrete technologies and prefabrication are well-represented by the technical publication issued during those years: in the USA, the American Concrete Institute (www.concrete.org) issued Special Publications on the topic, such as the material standards of production in the ‘50s; in Europe, the advancements in concrete technology and standards were widely illustrated in technical publication issued by association such as *fib* - Fédération internationale du béton (www.fib-international.org), British Precast (www.britishprecast.org) and journals such as *Concrete Quarterly* (published from 1948 by the Concrete Society www.concrete.org.uk), and even in Italy in *L'industria Italiana del Cemento* (from 1929).

the consideration of different aspect, including the choice of materials and adequate ordinary or special casting processes, in order to attain homogeneity of the visible surface (uniform colour, no trace of resumption casting, planarity) or rather the absence of defects (honeycombing, slumping, sand scouring, rust stains).
Necessary measure and specific aspects to take into account are generally listed in handbooks and include the source of materials (plant and quarry), the granulometry testing, the constant mix proportions, one type of mix per mixer, attention to prevent segregation during transportation, as few casting resumptions as possible (maximum height of 5 m), minimum casting speed 1.5 m/h (surface blow-holes), casting compaction to reduce blow-holes complying with minimum distances for the cover, non-metallic spacers; while others aspects, mainly the water/cement ratio, might enable other phenomena, such as local segregation of water or cement or shrinkage crazing due to low values.
Also formworks for casting highly influence the results, as it happens for wood (effects of material absorption, effect of waterproofing, surface treatments), steel (rust, blow-holes) or plastic moulds (complex forms, blow-holes); in the case of precast concrete elements, these effects can usually be avoided with a proper testing of the formworks/moulds in the production process. Anyway, some experimental precasting methods, developed between the '60s and the '70s, such as the use of special plastic formworks to create decorate surfaces, later reveal more degradation issues.

Concrete durability, as the ability to last a long time without significant deterioration, is related to physical and mechanical features of the materials and is considered a fundamental property to ensure that safety levels are maintained throughout the life of the building (D.M. 14/01/2008). It depends on raw materials used, on their ratio, on workability, on the cement content and the processing, mixing, and curing (standards specify the requirements according to the exposure classes).
Ordinary causes of concrete deterioration, in fact, are often intrinsic, related to concrete composition and processing, such as mix design, water/cement ratio, aggregate/cement ratio, quality of raw materials, techniques used in casting, structural use. Precast concrete components, as controlled-quality factory-made products, usually show less defects and property problems than cast in-situ concrete elements. However, these defects might be present even in precast concrete panels, especially when particular solutions were driven by aesthetic research or experimental approaches.

While general properties of concrete, such as permeability and porosity, determine a certain grade of durability, other characteristic of exposed and precast concrete might determine the presence of defects, such as *cold-joint lines, honeycombing, air voids and bugholes* (F. 2-16; F. 2-17; F. 2-18). Design and construction defects are quite common in modern in-situ concrete works, while they are more rarely detected in contemporary precast concrete components.
More severe causes of deterioration are usually external, influenced by the environment, location and exposure, and especially chemical (oxygen, carbon dioxide,

sulphates, sulphides, chlorides, alkali), physical (freeze-thaw cycles, essication-shrinkage, high temperatures) and mechanical (abrasion, erosion, cavitation).
Anyway, deterioration of concrete can be avoided by paying attention to the design and carefully considering the environment in which this will be put in place. The technical standard UNI 11104: 2004 (Concrete: Specification, performance, production and conformity - Additional instructions for the application of EN 206-1), in fact, identifies six exposure classes, for each of which directions are given for the design, production and casting of concrete (maximum water/cement ratio, minimum resistance, minimum cement, minimum concrete cover).
Furthermore, one of the most relevant phenomena in reinforced concrete elements is the corrosion of metal reinforcements, which occurs in many precast concrete elements, especially panels, due to the limited thickness of the cross-section. There are two primary ways the process can be activated: the passivation through carbonation of the concrete or penetration of chloride, which led to the oxidation (transformation of steel into rust - porous, friable, voluminous iron oxides), the cracking, and expulsion of the concrete cover.
In addition to chloride attack and carbonation, concrete can be subject to acid and sulphate attack - a serious cause of deterioration is the sulphate attack of the cement matrix, defined as ESA (External Sulphate Attack) and ISA (Internal Sulphate Attack).
Chemical reaction of aggregates, aggressive chemical exposure, presence of biological matter on the surface of the concrete, and damage resulting from freeze-thaw cycling also facilitate the corrosion of the reinforcement and/or cause cracking of the concrete cover. Factors external to the concrete material itself, such as poor detailing, poor drainage, problematic finishes, inadequate design for actual loadings, and inadequate maintenance (Meloy, 2016) can exacerbate these and other pathologies.

Additionally, also the <u>surface</u> of concrete might be subject to <u>pathologies</u>, including leaching by acid water (erosion or solubilisation), micro-cracking caused by variations in temperature and humidity or by static/dynamic stress, discoloration and other change in appearance.
Italian technical standard [115], define the framework for the recognition of the pathologies of concrete, introducing the distinction between the alteration and degradation and identifying each morphologies with specific definition and description[116].

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[115] Italian technical standard UNI 11182: 2006 "Natural and artificial stone, Description of the alteration - Terminology and definition", which replace the previous regulation on stone NORMAL 1/88 can be applied also to concrete as a type of 'artificial stone' in addition to natural stone, mortar, plaster, and ceramic products.

[116] The standard UNI identifies degradation morphologies with a specific vocabulary and define each one through a unique description. Recent studies and publications have then proposed a re-elaborated version of the scheme specifically dedicated to concrete works (Di Biase, 2009) Other technical documentation on concrete deterioration and the mechanism involved: (ACI, 2008) and (CS, 2000).

Precast concrete panels are subject, in addition to the pathologies that affect general reinforced concrete, to numerous specific mechanisms of deterioration to due to their composition and the nature of the wall system they comprise (Meloy, 2016). On the one hand, the geometrical and dimensional features of the wall panels exacerbate some deterioration mechanisms (F. 2-19 to F. 2-27). The narrow cross-section, thinner than in cast-in-place concrete walls, increases the risk of bowing and distortion, which can lead to cracking and exposure of the reinforcement. Insufficient or misplaced reinforcement, due to the section shape, might also lead to cracking. The narrow cross-section also determines less concrete cover of the reinforcement, which can lead to faster carbonation of concrete and, subsequently, depassivation and corrosion of the reinforcement, and cracking, delamination and spalling of the concrete cover. The vulnerability of the reinforcement can be exacerbated by reactions of the concrete aggregates, such as alkali silica reaction, which leads to cracking and easier penetration of carbonation. Moreover, the thinner cross-section of precast panels makes them more sensitive to temperature changes and expansion/contraction mechanism, leading to deflection and cracking if proper joints and restraints are not provided.

Secondly, cracks and other defects can result from the production process, due to improper trowelling of the concrete during the casting process or to concrete shrinkage occurring during the curing process (i.e. steam curing), while cracks may develop also when the elements are stripped from the formwork and especially during handling and transportation. Common damages in precast concrete elements (fractures and cracking) may occur due to transverse shrinkage, improper handling or improper reinforcement placement (longitudinal cracking), longitudinal shrinkage, heat-curing, excessive fibre tension or insufficient cover on transverse reinforcing bars (transverse cracking), surface shrinkage, improper trowelling or improper mixes (miscellaneous cracks)[117].

Moreover, precast concrete systems are characterised by connections and joints, which are the most critical areas and can significantly contribute to deterioration and damage of the panels or the entire façade system or structure[118].
The joints prevent moisture and air to penetrate the wall system and lead to condensation problem, which can cause discoloration of the panels and corrosion of the connections. Moisture can also move along the surface of the panel, resulting in erosion of the cement paste and, consequently, increased concrete porosity.

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[117] A comprehensive review of cracks in concrete and their causes is presented in the technical documentation by the American Concrete Institute (ACI, 2007).

[118] The fundamental role of connection in prefabricated structures is well-established in literature, however a significant reference on the topic is presented in the *fib bullettin 34* (fib, 2008).

Condensation and moisture in the wall system are also affected by freeze-thaw cycles, causing expansion and contraction of the panel, spalling, and delamination.
In addition, the deterioration of the joint material between the panels can impede the panel's ability to accommodate differential movement and lead to cracking and chipping.
Connections (the seat connection of the panel, the tie-back to the structural frame, and connections to control lateral movement) are vulnerable elements due to factors such as unintended forces introduced into the wall system (i.e. seismic event, as discussed in paragraph 2.2.1) and accidental eccentricities occurring during the production and erection phases, which can overload and weaken the connection material, ultimately leading to connection failures.
Additionally, the connection material is also subject to degradation and corrosion[119] if exposed to moisture or other atmospheric agent, even resulting in damage of the panels such as fractures, chipping, and excessive wall movements.

[119] The problem of corrosion of the connection material is particularly critical when referred to element fabricated with non-corrosion resistant materials. However, even hot-dipped galvanized steel connection assemblies, later introduced, could eventually corrode, especially when in contact with dissimilar metals, mortar, or concrete.

Protection and repair of precast concrete components

In general, interventions for the preservation and repair of concrete constructions are aimed to restore the static safety of the structure (i.e. seismic upgrade), reactivate the functionality of the structure, and improve o renovate the appearance of the building.
Specific objectives of the maintenance and repair operations are the reduction or removal of the causes responsible for structural deficiencies, loss of functionality or aesthetic alterations of the building. Additionally, the operations are intended to eliminate the structural collapse and stop the degradation and other forms of decay of the materials. Most importantly, the preservation and repair strategies are meant also to protect the buildings from further degradation for their entire useful life.

As regards industrial building made with prefabricated concrete structures and precast concrete wall panels, the most substantial interventions consist in seismic upgrade of the structures or structural upgrade using composite systems. On the other hand, the repairing of fair-faced concrete elements generally includes the cleaning of the concrete surface, the reconstruction of the damaged section of the reinforced concrete elements, the sealing and injection of cracks and honeycombs, and the waterproofing of the eaves (Coppola and Buoso, 2015).
The preservation and repairing strategies appears to be, however, fairly limited when dealing with fair-face and exposed aggregate concrete. The most important feature of this concrete technology is often the architectural expression obtained through the specially designed shape of the elements, the facing concrete mix and the surface finish and/or treatment applied to it. Thus the current approach tends to prioritise these aspects, avoiding, if possible, methods which might compromise the original appearance of the concrete elements.
European standards define procedures and products to be used for the repair, maintenance and protection of reinforced concrete structures (UNI EN 1504 - Products and systems for the protection and repair of concrete structures - Definitions, requirements, quality control and evaluation of conformity). The standard is aimed to provide valid tools in order to optimise the repair intervention and avoid simplistic approaches, such as undifferentiated replacement, which sometimes characterised concrete restoration in the past. Instead the standard makes clear the innovative features of the restoration according to the CEN (European committee for standardisation) vision, pointing out the protection and repair objectives, their minimum requirements and the principles for the selection of products. In addition, the importance of subsequent operations of investigation is pointed out, starting from the evaluation of the degradation causes, the definition of principles for intervention, the selection of the adequate methods of repair, and then the choice of materials and identification of their specific requirements.

In this sense, the most appropriate type of intervention should be selected taking into consideration the cause or combination of causes that led to deterioration (i.e. causes of defects in concrete, causes of corrosion in steel reinforcement). However, the type of intervention to be applied depends also on various factors which characterise each building, which range from general factors, such as intended use and service life, to health and safety issues, or structural and environmental aspects (UNI EN 1504-9:2008: General principles for the use of products and systems).

The selection of products and systems for repair or protection on a structure is therefore based on an analysis of the principles and methods which best satisfy them. The standard introduced the most significant principles, methods and products related to repair, maintenance, protection, renovation and consolidation of concrete structures in different parts[120]. More specifically, some methods are specifically aimed at defects in concrete, while others are connected to degradation due to corrosion of the reinforcement.

Relevant work on precast concrete panels include the protection against ingress of aggressive agents, reducing or preventing the entry of liquids, vapours, or gases, the moisture control, in order to adjust or maintain the moisture content in concrete within a specific range of values, and concrete restoration, which bring back the concrete of an element of the structure to its original form and function. Other intervention for the structural strengthening, gripping and repair are applicable to concrete structures but are not so relevant for the use for precast concrete panels.

Methods related to the corrosion of the reinforcement are based on the preservation and restoration of the passivity, the increase of resistivity, the cathodic control and protection and the control of anodic areas.

Surface protection systems for concrete (UNI EN 1504-2:2005) could be used to fulfil five of the above principles, and includes methods such as hydrophobic impregnation, impregnation, surface coating, overlay or coatings, whose main difference lie in the level of impregnation and the subsequent changes in the appearance of the original concrete surface finishing (F. 2-28 to F. 2-33).

Furthermore, products and systems for injection and for non-structural repairs are intended to restore the integrity and/or durability of the structure but also the geometric and aesthetic appearance of the elements.

However, some of the methods, such as the addition of overlays, coatings, mortar or concrete (UNI EN 1504-3:2006) might result not adequate to precast concrete cladding elements due to the substantial changes in appearance that they determine, compromising the main aesthetic and formal features of the fair-face concrete.

[120] UNI EN 1504-2:2005 Surface protection systems for concrete, UNI EN 1504-3:2006 Structural and non-structural repair, UNI EN 1504-4:2005 Structural bonding, UNI EN 1504-5:2005 Concrete injection, UNI EN 1504-7:2007 Reinforcement corrosion protection.

<u>Cold-joint lines:</u>
visible lines on the surface formed concrete indicating the presence of joints where a layer of concrete had hardened before subsequent concrete was placed.

F. 2-16: cold-joint lines in a cast-in-place concrete structure, warehouse in Martignacco, Udine (author, 2014)

<u>Honeycombs:</u>
voids left in concrete due to failure of the mortar to effectively fill the spaces among coach aggregate particles.

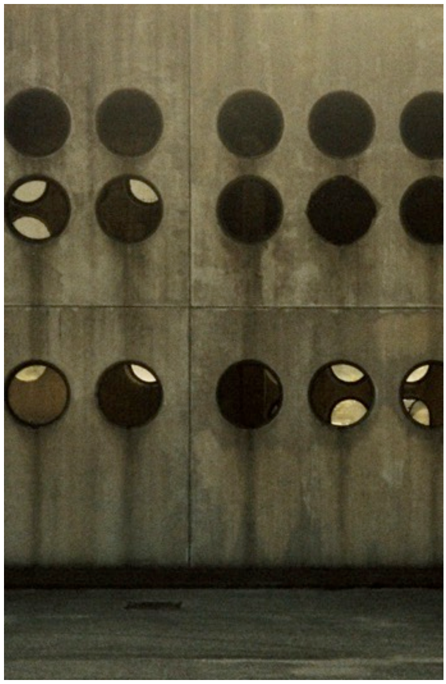
F. 2-17: honeycombing in the cast-in-place concrete beam, church in Baranzate by A. Mangiarotti (Coppola, 2015)

<u>Air voids:</u>
spaces in cement paste, mortar or concrete, filled with air.

<u>Bugholes:</u>
small regular or irregular cavities (usually not exceeding 25 mm in diameter), resulting from entrapment of air bubbles in the surface of formed concrete during placement and consolidation.

F. 2-18: bugholes in a concrete component (precast.org, 2013)

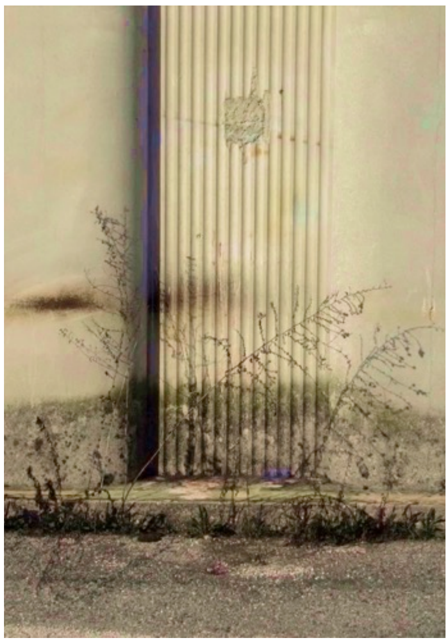
Unexpected variations in the visual appearance of the structure are the main weathering problems. Dust in the atmosphere might deposit on the façade, while the flow of rainwater tend to wash some areas preferentially, resulting in significant differences in colour between clean and dirty areas. It is however largely a cosmetic problem, unless it is allowed to concentrate.



F. 2-19: traces of trickling in precast concrete panels in an abandoned industrial building from the '70s, Tricesimo, Udine (author, 2014)

Trickling is usually present in a number of parallel traces, which might appear darker (deposit of material) or lighter (washing) and might lead to incrustation and erosion.

Biological growth:
organic surface growth (or patina) of micro-organism, algae, fungi, various types of bacteria, lichens, plats. Specific forms and finishing of the components, such blow-holes or rough surface, enable organic growth to become established. The presence of water or moisture increases the risks of biological growth.
It is correlated with staining and disgregation and it might be present together with mineral deposit, erosion and efflorescence.



F. 2-20: biological growth in the bottom part of precast concrete panels, Seleco plant, 1967, Pordenone (author, 2016)

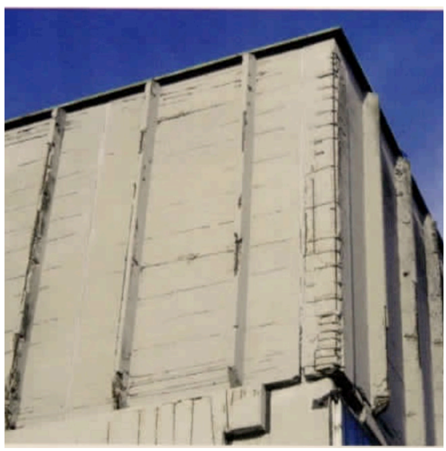
Incrustation:
a crust or coating, generally hard, formed on the surface of concrete or on aggregate particles. The causes are usually the deposit of dust in the atmosphere (pollution), shape and finishing of the elements.

F. 2-21: atmospheric dust deposit on concrete elements in an industrial building (Coppola, 2015)

Mineral deposit:
generic deposit of material - such dust, dirt, guano - characterised by variable thickness and low cohesion to the concrete surface.

Stalactite/stalagmite:
downward/upward-pointing deposit consisting in an accretion of mineral matter produced by evaporation dripping water from the surface of concrete. Main causes are the material composition and the presence of moisture or water infiltrations.

Scaling:
local flaking or peeling away of the near-surface portion of concrete. It is classified as light - loss of surface mortar without exposure of coarse aggregate, medium - loss of surface mortar 5 to 10 mm in depth and exposure of coarse aggregate, severe - some loss of mortar surrounding aggregate particles up to 20 mm in depth, or very severe - with loss of coarse aggregate particles. It is defined also dusting in case of the development of a powdered material. Main causes are weathering, freeze-thaw cycles and collisions or low-cement concrete. It is associated to exfoliation, erosion, biological growth.



F. 2-22: corrosion of the reinforcement and spalling in concrete panels in an industrial building (Coppola, 2015)

Delamination:
separation along a plane parallel to the surface, as in the separation of a coating from a substrate or, in the case of concrete slab, a horizontal splitting, cracking or separation of a slab in a plane roughly parallel to, and generally near, the upper surface. The causes might be intrinsic (materials), weathering or freeze-thaw cycles.

Efflorescence:
deposit of salts, usually white, formed on the surface of concrete; the substance emerges in solution from within concrete and subsequently precipitates by evaporation. Causes vary from concrete composition and hydrolysis to water infiltrations. It might be correlated to scaling, tickling and staining.

F. 2-23: efflorescence/incrustation and general discoloration in precast concrete elements in Spadolini pavilion, 1976, Firenze (author, 2016)

Erosion:
progressive disintegration of a solid by the abrasive or cavitation action of gases, fluids, or solids in motion (such as atmospheric agents).

Exfoliation:
disintegration occurring by peeling off in successive layers; 'swelling up and opening into leaves o plates like a partly opened book'. Material composition and production might help to enable exfoliation, freeze-thaw cycles.

Spall:
lack of fragment, usually in the shape of a flake, detached from a larger mass by a blow, by the action of weather, by pressure, or by expansion within the large mass.

F. 2-24: relevant spall in precast concrete elements in Spadolini Pavilion, 1976, Firenze (author, 2016)

Popout:
breaking away of small portions of a concrete surface due to localised internal pressure which leaves a shallow, typically conical, depression. Popout is classified as small - holes up to 10 mm in diameter, medium - between 10 and 50 mm, and large - more than 50 mm. It usually depends on concrete aggregates and processing and involves the entire structure. It might be correlated to micro-cracking.

Staining:
Local alteration of the colour of concrete surface caused by oxides and salts washed from metal items (copper, bronze for cladding or flashing). It mainly depends on design and construction solutions and affects only the appearance of the structure.

Discoloration:
Departure of colour from that which is normal or desired. It usually affects the entire structure/material (otherwise is considered staining).

Non-structural cracks (ACI, 2007):
Pattern cracking consist in fine opening on concrete surface in the form of a pattern (regular or irregular), resulting from a decrease in volume of the material near the surface of increase in volume of the material below the surface.
Plastic cracking occurs in the surface of fresh concrete soon after it is placed and while it is still plastic.
Shrinkage cracking occurs due to failure in tension caused by external or internal restraints (reduction in moisture content, carbonation).
Temperature cracking is caused by temperature gradient or differential in members subjected to external or internal restraints.
Transverse cracks develop at right angles to the long direction of the member.
Checking consists in shallow cracks at closely spaced but irregular intervals on the surface of concrete.
Craze cracks are irregular and random fissures in the surface of concrete.
D-cracking developed in concrete near and parallel to joints, edges and structural cracks.
Diagonal cracks occur in flexural members and are caused by shear stress, usually at about 45 degrees to the axis; in slabs they are usually not parallel to either the lateral or longitudinal directions.
Hairline cracks consist in micro-cracks in exposed concrete surface having widths so small as to be barely perceptible.

F. 2-25: degradation on precast concrete panels, abandoned warehouse-dealership from the ‘60s, Tavagnacco, Udine (author, 2014)

F. 2-26: degradation of concrete in an abandoned warehouse from the ‘70s in Tricesimo, Udine (author, 2014)

Reinforcement corrosion damages:

Rust spots produced by reinforcement corrosion affect the appearance of the structure.

Cracking consists in the complete separation along line of bars produced by reinforcement corrosion.

Delamination consist in the separation along a plane parallel to the surface caused by the corrosion of the reinforcing steel.

Spalling appears as fragments, usually in the shape of flakes, detached from a larger mass and caused by reinforcement corrosion.

F. 2-27: reinforcement corrosion damages in precast concrete panel with ribbed section, disused warehouse-dealership from the ‘60s in Tavagnacco, Udine (author, 2015)

F. 2-28: ARM Italia, Cinisello Balsamo, Milano, original concrete surface (Mangiarotti, 1973) - fiche 09

F. 2-29: ARM Italia, Cinisello Balsamo, Milano, new coating (author, 2015) - fiche 09

F. 2-30: Gabbioneta plant, Milano, original concrete surface - fiche 22

F. 2-31: Gabbioneta plant, Milano, new coating (author, 2015) - fiche 22

F. 2-32: Esselunga warehouse, original façade (Archivio Impresa Morganti, 1970) - fiche 13

F. 2-33: Esselunga warehouse, new panel-roof connection and coating (author 2015) - fiche 13

2.2.3 Performance degradation of industrial buildings: energy and environmental issues

Following a first phase of investigation on industrial architecture made by concrete and the use of precast elements for the building envelope, a second important phase of the research has focused on energetic and environmental aspects related to sustainability of industrial buildings. The previous phase on industrial architecture has allowed to contextualise the phenomenon of prefabrication in relation to the development of industrial areas in Italy during the last century and to identify the peculiarities of this built heritage (chapter 1). The analysis of the constructive and detail features has therefore provided an opportunity for the continuation of the work toward the energy-environment field, expanding upon the issues of quality and performance related to the typological and technological knowledge.
The aspect of sustainability for industrial buildings is still, in Italy, partly unexplored and the construction standard is far from an environmental performance considered adequate for other building uses; in addition, in the past, industrial buildings, excluded from many of the regulatory requirements until the '80s, were often designed and built with little consideration of the issue of energy saving, so that they opaque and transparent structures and heating systems have considerable energy performance deficit. Moreover, in Italy industrial buildings are also predominantly made by prefabricated building systems, very popular since the '50s and '60s due to their characteristics (such as the low cost of design and construction), respecting more quantitative parameters than the overall architectural and environmental quality.
Nowadays, according to the growing interest in sustainability of the industrial sector and the perspective of an increasing need for reclamation of abandoned or underused areas, the problem of reuse and adaptation (functional, structural and energetic) of existing industrial buildings raises, especially the most common types such as ‘sheds/warehouses’ constructed with prefabricated systems.
The objective of this part of the research was therefore the identification, with respect to the type of building object of study, of the major problems of energy-environmental quality, for a subsequent critical synthesis of the possible refurbishment strategies, considering international best practices and available technologies.
On this basis, first of all, the sustainability assessment through the energy and environmental audits prove to be fundamental, and the appropriate application of the latest methods, tools and certification protocols is addressed in relation to the knowledge of the building stock of the recent past.

Energy efficiency and environmental sustainability of the industrial sector

The interest in the issue of sustainability regarding industrial areas, followed by the spread of sustainable buildings and areas (Smets *et al.*, 2005; Bollini *et al.*, 2007; Fontanin *et al.*, 2008; Cancila *et al.*, 2010; Iraldo *et al.*, 2012a; Iraldo *et al.*, 2012b), however marginal, has grown in connection with several factors: the national and regional laws calling for new performance requirements for buildings and systems, the increasing use of renewable energy sources facilitated by public incentives, the specific regulations for industrial sector and EU directives and legislation, the implementation of standards towards an integrated energy&environment management of process and product (with the systems for environmental management ISO 14001, energy management ISO 50001, life cycle assessment ISO 14040, and carbon footprint ISO 14064), and, finally, the design and certification tools for the energy and environmental sustainability at international (LEED) and national level (ITACA).

In this context, the design and refurbishment of industrial buildings implies, in general, the application of energy and environmental strategies aimed at rationalising consumption, optimising systems and reducing pollutant emissions. The energy and environmental sustainability of buildings has taken a leading role also for the evaluation of the building stock and, as a multidisciplinary theme, is oriented to the industrial site as a whole, according to international research developments - SIAM Project, Life Programme, 2004-2007 (Tarantini, 2007); the MEID project, Mediterranean Eco-Industrial Development, 2010-2013 (Tarantini, 2013); Factories of the Future, Horizon2020 (www.effra.eu). Moreover, in Italy there has been much research on the transformation of industrial heritage, and, in recent years, several works have paid special attention to the relationship between sustainability and typological and technological characteristics of buildings (Ferrante, 2008; Bassi, 2008; De Paoli and Montacchini, 2008; Maspoli, 2014).

The topic of the renovation and upgrade of the existing industrial facilities is, in fact, the practical aspect of interest related to the sustainability of industrial buildings, and it involves the architectural issue of the restoration of the built heritage. In particular, the architecture of industrial buildings has favoured considerations on the themes of structure, building envelope and prefabrication by many authors (Dassori, 2001; Graf and Delemontey, 2012), while only recently the issue of energy and environmental quality have been investigated (Cinotto and Ferrero, 2009; Bucci and Mollo, 2010; Sanchini and Bertoli, 2014).

This multifaceted framework has implied different trends in research and methodologies, at national and European level, on the specific issue of energy and environmental quality of industrial building stock; only few works refer to buildings of the recent past ('50s - '70s), and application examples and documentation are rare. This has suggested to analyse, as the first point, the topic of the energetic-environmental assessment or audit. The energy and environmental audit, through the definition of a specific strategy for the assessment of the industries in the region, could also be a good basis for future developments of the study.

Energy and environmental audit of industrial buildings

In Italy, the current regulation on energy efficiency represent the basic reference for the assessment of the energy quality of buildings, and consists of guidelines and tools such as the certificate of energy performance (according to Legislative Decree no. 192/05 and now by the new guidelines for the energy certification of buildings in the MD June 26, 2015, and the technical regulations on energy saving and energy certification of buildings (UNI TS 11300). The Italian regulation for energy efficiency in building has evolved over time according to European Directives and international standars, with National and Regional Laws and with public incentives for energy efficiency and renewable sources. During the last years there have been several substantial updates to the regulation and, in 2015, three Inter-Ministerial Decree have been published to complete the regulatory framework in the field of energy efficiency of buildings. The *Decree on minimum requirements* includes the application of the calculation method of energy performance, definition of the standards and the minimum requirements; the *Decree on guidelines* for the new certificate APE[121] 2015 is an update of the previous decree (2009) on National guidelines for certification of energy performance of buildings; the *Decree on the technical report* includes the schemes and the references to draft the technical report of the project, in order to check the implementation of minimum requirements of energy performance.
The decrees introduce, according to European directives, new Energy Classes (from A4 to G) corresponding with a *Global indicator of energy performance* of the building (considering all the systems for heating, cooling, ventilation, illumination etc), overcoming the former distinction between winter and summer energy consumption. The indicator is based on the new minimum requirements for the overall heat transfer coefficient (U-value) for the elements of the building envelope. Finally, the new regulation recognise the importance of the building envelope introducing two additional indicators: the winter performance of the building envelope (index of thermal performance for winter heating, related to thermal transmission, insulation and ventilation system), and the summer performance of the building envelope (index of thermal performance for air-conditioning, related to summer overheating, transparent surfaces and thermal mass).
The regulation considers the building performance according to their intended use and categorise manufacturing buildings as E.8 - buildings used for industrial and craft or similar activities.

However, even if the energy efficiency is one of the most important aspects to be considered, the environmental sustainability of construction works implies to take into account a wider set of topics. In this sense, the APE certificate, as a compulsory

[121] Certificate of energy performance of the building - *Attestato di Prestazione Energetica dell'edificio* - APE.

document, drafted in compliance with the national law by a qualified and independent certifying expert, is meant to assess only the energy performance of a building through the use of specific criteria and to provide recommendations for improvement of energy efficiency. As energy efficiency constitutes only a part of the evaluation of the level of environmental sustainability of buildings, the tools for sustainability assessment therefore examines various other aspects: the use of raw materials and water, the management of waste and the impacts on site. Furthermore, the assessment of sustainability is oriented to a wider physical and temporal setting, considering the building in its evolution over time, according to a life cycle cost approach, the building site and the building impacts on the neighbouring context. The analysis of the performance, weather organised upon a check-list (LEED) or an analytical structure (SBtool), is usually based on a quite-large set of criteria which allow to classify the building on a simplified quality scale (score or label).

In the Italian context, this approach is implemented in the ITACA Protocol (iiSBE), introduced in 2004 and became a UNI Praxis in 2015, as a tool to assess the level of sustainability of construction works. The protocol has been developed for different building types (residential, office, school, retail and industrial buildings); it consists in an operational tool, based on multicriteria analysis, defined for the assessment of the sustainability of buildings and for their classification through the assignment of a score of performance[122].

The reference for the evaluation of possible interventions has been identified in the ITACA Protocol - Industrial Buildings[123]. A first issue considered by the ITACA Protocol is the *Site regeneration and development* (A), including aspects of the *Site selection* (A.1), with criteria about the level of *Site regeneration*, the accessibility to *Public transportation*, the presence of *Mixed uses in the area*, or the *Proximity to Infrastructure,* and the quality of *Urban design* (A.3), such as the *Provision of public open space* and *bicycles spaces.*

The aspect of *Energy and resource consumption* (B) is considered in terms of energy as *Total life-cycle non-renewable energy* (B.1), with the assessment of the use of *Primary energy for winter heating* or *for hot water*, and *Renewable energy* (B.3), with the measure of *Renewable energy for thermal use* and *Renewable energy produced on-site for electric use.* In addition, the *Use of eco-friendly materials* (B.4) is evaluated, considering the percentage of *Reuse of existing structures*, the choice of

[122] The ITACA Protocol considers, as the objects of the evaluation, the buildings and their adjacent lots; the performance is analysed through a combination of specific criteria and the result of the process is a score (from -1 to 5) and a classification of the building environmental quality (good, excellent).

[123] The Protocol scheme consider three hierarchic levels of evaluation of sustainability: the assessment areas (3), meant as general issues related to environmental sustainability which implies the definition of main objectives and strategies, the assessment categories (19), or sub-issues, homogeneous groups of criteria, i.e. water, resources, materials, and the assessment criteria (about 37), specific rules for determining whether a building has or not certain qualities, in order to assess if a given property or relation is satisfied (ITACA *et al.*, 2011).

Recycled materials, Materials from renewable sources, *Local materials, Local materials for finishing, Recyclable materials*, and *Certified materials.* In the same area, also the *Use of potable water* (B.5), as *Potable water for irrigation* and *Potable water for indoor use* is estimated*.* Finally the evaluation focus on the *Building Envelope performance* (B.6) taking into account the consumption of *Net energy for cooling*, the *Thermal transmittance of the building envelope*, the strategies for *Daylight control*, and the *Thermal mass of the building.*

Environmental Loadings (C) are estimated according to the level of *CO_2 emissions* (C.1), the production and management of *Solid waste* (C.3) and *Waste water* (C.4), such as draining of *Grey water* or *Permeability of soil,* and the other *Impacts on site* (C.6), such as the *Heat island effect.*

The aspect of *Indoor Environmental Quality* (D) is influenced by the aspects of *Indoor air quality and ventilation* (D.2), *Air temperature and relative humidity* (D.3), *Visual comfort* (D.4) as *Daylighting and illumination*, *Noise and acoustics* control (D.5) and *Control of electromagnetic emissions* (D.6).

Finally the *Service Quality* (E) is briefly considered in terms of *Functionality and efficiency* (E.2) of *Data-transmission system, Controllability of systems* (E.3) and *Optimization and maintenance of environmental operating performance* (E.6) through the *Maintenance of the building envelope performance* and the *Availability of technical documentation.*

It must be noted that the international assessment tools (SBtool) usually allow also the evaluation of two more issues: the social, cultural and perceptual aspects, and the cost and economic aspects of sustainability.

Finally, a relevant tool and methodology to assess the environmental performance of buildings is the energy audit procedure. The energy audit is meant as a *technical and economic evaluation of energy flows*, carried out through a systematic set of operation including survey, collection and analysis of the parameters related to the specific consumption and the operating conditions of the building and its systems. Differently from the APE certification, which is based on standard parameters for the building use and operating condition (standard values of temperature etc.), the Energy Audit focus on the very energy use (real values) of the building analysed.

European standard define the minimum and specific requirements (UNI CEI EN 16247-1:2012), procedures and role of auditors (UNI CEI 11339) for energy audits of buildings and building envelopes (UNI EN 13187) and also for systems of energy management (UNI CEI EN ISO 50001:2011).

In recent years, the Energy audit procedure has been proposed in other extended versions in order to include the assessment of environmental sustainability aspects. Such is the case of the *Green energy audit* scheme (Dall'Ò, 2013), in its two versions - *standard audit* and *walkthrough audit*, which therefore represent an useful tool for the evaluation of industrial buildings.

The assessment of environmental sustainability of buildings in an industrial district: a case-study in the Friuli Venezia Giulia region

The theme of energy and environmental assessment and redevelopment of industrial areas and buildings was further developed in relation to the regional context and with the aim of documenting the current condition of the industrial building stock, providing its assessment on the basis of energy and environmental parameters and finally envisaging proposals for future redevelopment of industrial areas and districts. The analysis was organised in a series of consecutive phases and was characterised by a change of scale, starting from a general overview on a regional scale, to get to the analysis of some particular applications on a building scale[124].

The first phase has involved an overview of the general features of industrial building in the regional area of Friuli Venezia Giulia (F. 2-36), through the collection and analysis of the available data and documents. A first evaluation of the industrial building stock was made possible by the cartography about land use in the region (ISPRA, 2000), which summarise the evolution of industrial buildings and areas from the '50s to the 2000s. Then the data of the eight industrial districts recognised by region have been added to the cartography (Silvestri, 2009); in particular, to address the analysis to a limited field of study, the work refers to the current organisation of the ten consortia for industrial development in the region and their sites[125]..

The second phase expands upon the typological and technological aspects of the buildings in the industrial district chosen as a case study (F. 2-36): it is the industrial district in Maniago (Pordenone), pertaining to the NIP Consortium[126] The regional cartography concerning the municipality of Maniago and the maps of the Consortium have been used as a basis to categorise the buildings in the district; the functional and dimensional information on the buildings (use, date of construction, areas and volumes) have been gather/deducted from the acquired data, while the typological and technical information have been revealed directly through surveys and interviews.

In the third and final phase, aspects of performance of the building stock have been analysed according to the main tools and methods for energy and environmental audit

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[124] This part of the study was developed by the author during the training and research period at the Regional Agency for Sustainable Building of Friuli Venezia Giulia - *Agenzia Regionale per l'Edilizia Sostenibile* - ARES-FVG, regulated by a Convention between the Agency and the University of Udine, for activities dedicated to the theme of energy and environmental assessment and redevelopment of areas and industrial buildings.

[125] The ten Consortia for Industrial Development of the Friuli Venezia Giulia region - *Consorzi di sviluppo industriale* are listed in the Region website, last update 2015: www.regione.fvg.it/rafvg/cms/RAFVG/economia-imprese/industria/FOGLIA5/.

[126] Consortium if the province of Pordenone, *Consorzio per il Nucleo di Industrializzazione della Provincia di Pordenone,* NIP www.nipmaniago.it

of buildings, including the tools for calculating the energy performance and the protocol for assessing the environmental sustainability.
Data on energy and environmental audits of the building in the district have acquired from the documentation developed by the European project Energy VilLLab[127], of which ARES-FVG has been partner, for the part relating to the issues of energy savings in industrial areas (Sanchini and Bertoli, 2014).
The basic reference and tools used for the assessment of the energy quality of the industrial buildings are: the certificate of energy performance of buildings (according to Legislative Decree no. 192/05 and now by the new guidelines for the energy certification of buildings in the MD June 26, 2015, and the technical regulations on energy saving and energy certification of buildings (UNI TS 11300), taking into account the requirements for category manufacturing buildings (E.8 - buildings used for industrial and craft and similar activities). A further important reference, especially for the evaluation of possible interventions, has been identified in the Protocol ITACA for Industrial Buildings (ITACA *et al.*, 2011), which added to the energy aspects the factors of environmental sustainability. For the assessment of individual buildings, acquired by the final report of the European project, the *Green energy audit* scheme has been used (Dall'Ò, 2013), in its two versions (standard audit and walkthrough audit).

There are eight industrial district recognised by the region of Friuli Venezia Giulia (Silvestri, 2009) and they are characterised by a building stock which is widespread in the industrial zones of several neighbouring municipalities and includes buildings built in various dates. The comparison between the regional maps on land use (ISPRA, 2000) and the data on industrial districts and the Consortia for industrial development (RFVG, 2015) has led to a first evaluation of the features of industrial buildings in the region. These industrial areas have originated and consolidated in the period between the '50s and the '70s, while only few have developed (or expanded) in a more recent period, since the '80s. A first analysis confirms that these areas are also characterised by manufacturing sites of small/medium size, including buildings mainly constructed in the same period (the '60s and the '70s) and sometimes expanded or renovated in the following decades.
The industrial area in Maniago (Pordenone), chosen as a case study, is managed by the Consortium for industrial development of Pordenone (NIP), hosts about 70 companies whose activities are mainly related to the 'Knife District', and covers a total area of 168 hectares, of which 165,220 square meters still available for new settlements.
The choice of an industrial area to study which is geographically confined has facilitated the processing of data and has simplified the synthesis of the results

[127] The Energy VillLAB project was funded under the Programme for Cross-Border Cooperation Italy-Slovenia 2007- 2013 2014. *Energy ViLLab Living lab for sustainable development,* available at www.energyvillab.net.

according the research topics. This has allowed the census of all the buildings within the area and the organisation of the information acquired in a georeferenced database. This has also supported the development of a series of thematic maps on several characteristics of the industrial area, such as maps categorising buildings by the date of construction (F. 2-37) or otherwise by the construction system (F. 2-38) or even by energy performance. Regarding the construction features of the buildings in this district, the analysis show that they're constructed since the 60s (not indeed present buildings prior to the '50s), with the typical building systems for industrial sites (F. 2-34). In detail, the walls are mainly made with precast concrete structures and panels, with cast-in-place concrete structures and masonry in brick or concrete blocks, with cast-in-place concrete structures and sandwich panels in metal sheet and insulation, or with steel-frame structures and curtain walls. The roofs are made with the same construction systems, such as prestressed concrete tiles or prefabricated shed elements, floors in brick-concrete, metal trusses and framed structures and sandwich panels with metal sheet and insulation, sometimes with the addition of ceiling and insulating panels in mineral wool. The types of windows have more variety: iron frames and single glass or polycarbonate (often fixed-type), insulated aluminium doors and windows with double-glazing, combined double windows, or insulated windows with special glass (Sanchini and Bertoli, 2014). Survey and observation on the field, in the area of study, have confirmed the presence of the types listed above, and has allowed to determine the amount of each type of building (Table 2-2).

The energy *audit* carried out on some sample buildings suggests the possibility of extending this assessment to the whole district, promoting the collection of information on energy and environmental aspects that can complete the typological-constructive knowledge of the industrial buildings.

The *Green energy audit* scheme (Dall'Ò, 2013) in the *walkthrough audit* version (in the form of a checklist), has proved to be a simple and fast assessment tool but also a suitable way for a more accurate preliminary estimation of energy and environmental quality of the building; furthermore, it provides a summary of the general characteristics of the building (size, dates), information on the building envelope and on the systems, and data on the current management. The *standard audit* collects thoroughly information on the building features, especially on building envelope and systems, from the description of the vertical and horizontal structures and the construction methods and materials, to the details of the thermic-physical parameters of the elements of the 'thermal envelope', and even to the identification of specific problems of some elements or systems or management aspects. The audit also includes the standard energy analysis (consumption, management and energy performance) and the possible improvement measures including the comparison of solutions in terms of energy performance, CO_2 emissions and economic costs.

So, for instance, the walkthrough audit of a sample building of the type 'precast concrete structures and panels', dated 1961-1971, shows that, despite the absence of degradation, the presence of thermal insulation in prefabricated elements and some recent upgrading works (such as the installation of double windows), the structure as a whole has deficit of energy performance. On the contrary, although the renovation of the façade or the replacement of windows are not currently planned, an improvement of the energy performance would be easily achievable through the addition of an external insulation layer or the installation of solar panel on the roof (Sanchini and Bertoli, 2014).

The analysis of the heat loss and the comparison of the energy performance of the sample buildings, for which the audit was performed under the EnergyVilLab project (Sanchini and Bertoli, 2014), is of particular interest in order to synthesise the main problems, highlighted by the percentage of consumption of opaque and transparent structures, and to define the incidence of possible retrofit interventions, related to savings percentages (Table 2-3).

Focussing on the heat loss from the building envelope, the analysis of each case show that the percentage of heat loss is ascribable for the most part to the opaque and transparent vertical structures (walls and windows), in a significant way even to the horizontal structures (roofs), while only marginally to the ground floors. Consequently also the savings percentages, achievable through refurbishment, are more relevant if they involve the vertical structures, consistent for the roofs, and not very significant for the ground floors (Table 2-4).

The proposed assessment method could be extended to the whole industrial district, making also possible to roughly estimate the major problems and improvement potential through the comparison of these results, from the audit on sample buildings of each type, with the buildings in the area, detected and classified by their constructive features.

The case-study has confirmed the importance of some issues involved in the research, and in particular the role of energy and environmental sustainability in relation to the dynamics of transformation of the industrial heritage of the recent past. The importance of the knowledge and evaluation, above and beyond the proposals and strategies for the renovation of the building (functional, structural, energetic) is confirmed. In fact, despite an ostensible homogeneity of industrial buildings in the context analysed, the process of assessment has pointed out several problems related to the acquisition of data for the knowledge (about both buildings and systems) and to the use of the tools for energy and environmental sustainability assessment (due to the complexity of the structures and the heterogeneity of possible interventions). As an additional outcome of the work, on the basis of the process already accomplished, the time and cost for the assessment are estimated; the evaluation of the environmental sustainability of the industrial building stock could therefore be continued, using the methodology proposed, going from the building scale to the district scale, and eventually to the whole Region.

type of wall	panels	number	%
prefabricated structure and precast concrete panels	vertical	15	27
	horizontal	16	29
	other forms	6	10
		37	67
cast-in-place concrete structure and masonry with bricks or concrete blocks		6	11
cast-in-place concrete structure completed with sandwich panels in metal sheet and insulation		5	9
concrete or metal structure and wall in concrete blocks		1	2
concrete or metal structure and cladding in other materials		6	11

Table 2-2: types of buildings in the industrial district in Maniago (Pordenone): numbers and percentages of buildings, categorised by systems and types of building envelope, with detail on precast concrete walls.

building elements	description	% heat loss	% energy saving*
opaque vertical structures	walls	31 ÷ 35	16 ÷ 26
horizontal structures	ground floors	5 ÷ 8	1 ÷ 3
horizontal structures	roofs	19 ÷ 44	8 ÷ 29
transparent elements	windows, doors, overhead doors	26 ÷ 39	6 ÷ 24
transparent elements	building with large windows	26 ÷ 49	25 ÷ 68
thermal bridges	-	2 ÷ 4	-
ventilation	mechanical ventilation system	50 ÷ 80	25 ÷ 68
systems upgrade	heat generator replacement	-	20 ÷ 26

* decrease in consumption related to building envelope

Table 2-3: comparison between heat losses and potential energy savings for each building element, according to energy audits carried out for the sample-buildings in the industrial district; summary of data from EnergyVillLab report (Sanchini and Bertoli, 2014).

building elements	type 1: precast r.c. structure and panels, saw-tooth roof (% heat loss)	type 2: cast in place r.c. and bricks, saw-tooth roof (% heat loss)	type 3: cast in place r.c. and sandwich panels, pitched roof (% heat loss)
opaque vertical structures	9,80	34,00	31,50
horizontal structures	5,40	7,60	8,20
horizontal structures	44,30	6,20	30,50
transparent elements	36,70	-	26.90
transparent elements	-	48,60	-
thermal bridges	3,80	3,60	2,90

Table 2-4: comparison between heat losses for each building type and element, according to energy audits carried out for the sample-buildings in the industrial district; summary of data from EnergyVillLab report (Sanchini and Bertoli, 2014).

Energy retrofit of industrial buildings - criteria, implementation of technologies and examples

When dealing with the issues of energy and environmental performance, the assessment tools constitute a fundamental basis also for the evaluation of the possible retrofit strategies and methods. This is why an interesting classification of the possible retrofit intervention for the building envelope, proposes a correlation between the technical solutions and the assessment criteria defined by the tools for sustainability assessment[128]. In this sense, each retrofit action might improve the ranking of the building according to some specific assessment criteria and therefore results more or less significant. In detail, the effect on the environment is estimated in terms of energy savings, comfort improvement and environmental impacts.
The considerations about the convenience of the possible intervention on each - if obsolete - part of the industrial building envelope are synthesised in the scheme below (Table 2-5). Some solution appear to be more or less adequate for each building element in terms of potential energy saving, payback, reliability, or feasibility. Such is the case of the addition of thermal insulation, especially combined with ventilation, in roofs and walls, which however implies substantial modifications of the building appearance and quite high costs (longer payback period).

In general, the retrofit solutions range from the addition of insulation layers or other functional parts to the complete replacement of the building element; moreover, new materials and technologies are often adopted in refurbishment project, and many possibilities have been introduced additionally to traditional ones. Alternative solutions for industrial building generally include the integration of renewable energy sources or propose the use of green roof and walls.
Both green roofs and solar photovoltaic systems are considered a particularly suitable solution for industrial building (Sassi *et al.*, 2007; De Paoli and Montacchini, 2008), due to the wide roof area available in common single-storey structures with flat roof.

[128] The full scheme, which however include the assessment of many other aspects - such intervention on the thermal systems etc., is published in (Dall'Ò, 2013) The same approach was adopted by EnergyVilLab project for the definition of guidelines on retrofit solution for industrial buildings (Sanchini and Bertoli, 2014).

	retrofit solutions for the building envelope	relevant parameters and evaluation elements	convenience	potential saving	payback	reliability	feasibility	effect on the environment
Pitched roofs	Upper thermal insulation of the pitched roof (insulation layer under the roof covering)	U, λ, ρ, μ, sound-proof, materials	B	3	2	3	3	E-C
	Lower thermal insulation of the pitched roof (insulation layer in the ceiling)	U, λ, ρ, μ, sound-proof, materials, integration, finishing		3	2	3	3	E-C
	Replacement of the roof with insulated and ventilated roof	U, λ, ρ, μ, sound-proof, materials, ventilation, finishing						
Flat roofs	Upper thermal insulation of the roof (inverted roof)	U, λ, ρ, μ, sound-proof, mechanical strength, materials	A	4	2	3	3	E-C
	Upper thermal insulation of the roof (warm roof)	U, λ, ρ, μ, sound-proof, mechanical strength, materials	A	3	2	3	3	E-C
	Upper insulation of the roof with green roof	U, λ, ρ, μ, mechanical strength, materials, ventilation, installation and maintenance	B	4	2	2	2	E-C
	Lower thermal insulation of the roof	U, λ, ρ, μ, sound-proof, finishing, materials	A	3	3	3	3	E-C
	Addition of false-ceiling	U, λ, ρ, μ, sound-proof, finishing, materials	A	1	2	3	3	E-C
Floors	Lower thermal insulation of the floor	U, λ, ρ, μ, sound-proof, materials, integration						
	Upper thermal insulation of the floor	U, λ, ρ, μ, sound-proof, mechanical strength, materials						

Walls	External thermal insulation coating	U, λ, ρ, μ, sound-proof, mechanical strength, materials, finishing, support	A	3	2	4	2	E-C
	External thermal insulation layer with ventilated façade	U, λ, ρ, μ, sound-proof, mechanical strength, materials, type of cladding, anchor system	A	4	2	4	2	E-C
	Internal thermal insulation	U, λ, ρ, μ, sound-proof, mechanical strength, materials, interior finishing	B	2	3	4	3	E-C
	Green walls	type of system, density of leaves, distance from the wall						
Windows	Windows replacement	Uw, Ug, Uf, solar control, glass light transmittance, air permeability class	A	3	2	3	3	E-C
	Glass replacement on existing windows	Uw, Ug, Uf, solar control, glass light transmittance, air permeability class	B	2	2	3	2	E-C
Daylight control	External solar shading system	glass light transmittance and solar factor, wind resistance, mechanical strength , openness factor	A	3	2	2	2	E-C
	Internal solar shading system	glass light transmittance and solar factor, openness factor, moisture, fire resistance						
	Solar control glass	Uw, Ug , Uf, glass light transmittance and solar factor, air permeability class	A	3	2	3	3	E-C
	Green solar shading system	type of plants, distance from the wall, anchor system						

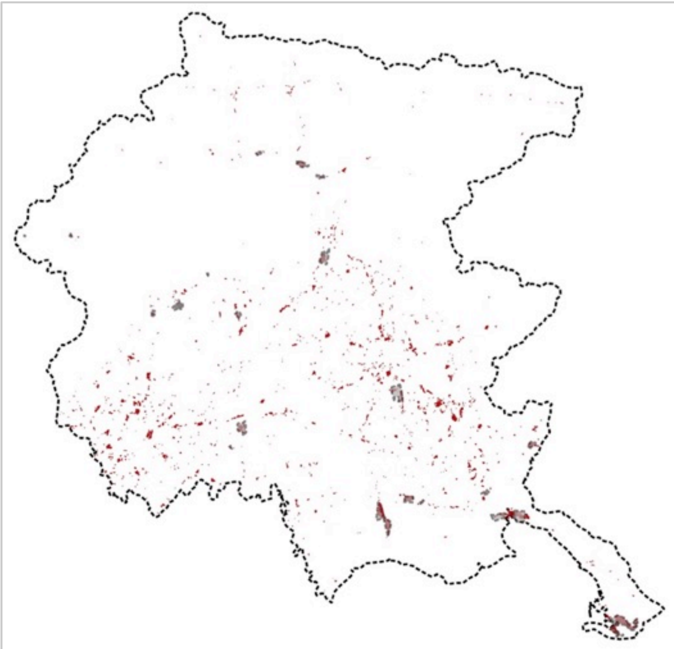
Daylight improvement	Coloration of the interior with bright and reflective colors	internal illumination, absence of glare, glossy or matte finish, eco-friendly paint					
	Installation of systems for light diffusion or internal blinds	material and transparency, solar factor, control system					
	Light chimneys and light shelves	type of chimney or shelves, light diffusion					
Integration renewable energy	Solar thermal system for domestic hot water	performance of solar elements, area and orientation of roof, shadows	-	2	3	3	3 E
	Photovoltaic solar system	performance and module type, area and orientation of roof, shadows		3	3	4	4 E

Effect on the environment:

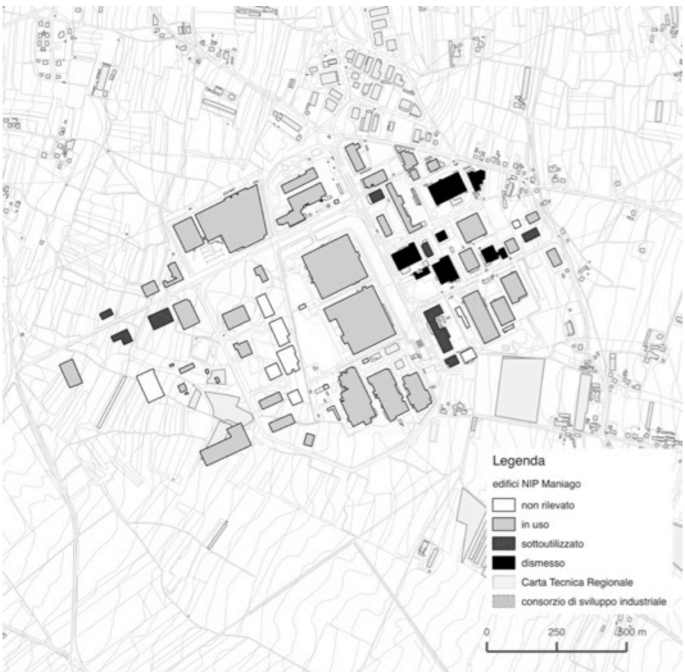
E - energy savings
C - comfort improvement

Table 2-5: retrofit solution for the building envelope, relevant parameters and convenience evaluation for industrial buildings, scheme adapted from (Dall'Ò, 2013; Sanchini and Bertoli, 2014)

F. 2-34: Industrial buildings in the district in Maniago, Pordenone: types of building, building systems and materials: reinforced concrete structures and sandwich panels, reinforced concrete structures and masonry in brick or concrete blocks, precast r.c. structures and precast concrete cladding panels (author, 2015)



F. 2-35: industrial areas - red - and consortia - gray - in the Friuli Venezia Giulia region (author's classification from the Moland map, 2015)



F. 2-36: Industrial buildings in the district in Maniago, Pordenone, categorisation by use: abandoned or disused, userused, used and new but empty buildings (author's classification from the Regional technical map 2015)

F. 2-37: Industrial buildings in the district in Maniago, Pordenone, categorisation by dates of construction, from 1970 to 2008 (author's classification from the Regional technical map and the Moland map, 2015).

F. 2-38: Industrial buildings in the district in Maniago, Pordenone, categorisation by building systems and types of wall, with detail on precast concrete walls (author's classification on the Regional technical map, 2015)

2.3 Perspectives and references for the reuse and transformation of industrial heritage

The study of precast buildings for industry, as a witness of the recent history of industrial architecture, is related to research concerning the wide theme of productive sites, from the discipline of industrial archaeology, to the issues of performance degradation and sustainability of industrial buildings, and to the theme of functional adaptation and adaptive reuse of buildings.
Industrial architecture is, in fact, more and more often subject of study, survey, valorisation and reuse, through an approach which is on the border between conservation and transformation. The understanding, protection, and evaluation of works of industrial architecture, already discussed in the preceding paragraphs, find a completion in the following discussion of the possibilities for reuse and renovation, physical and functional, of production facilities.

Contemporary theoretical issues about the transformation of industrial heritage are briefly discussed (paragraph 2.3.1), starting from the crisis of the industrial sector as the fundamental premise to reclamation of areas and conversion of building. The investigation considers the aspects of sustainability involved in the transformation of industrial assets, the principles and criteria for adaptive reuse of buildings and the current trends in functional adaptation and new uses for former manufacturing spaces.
The study then focuses on the design concepts applied in the adaptive reuse of industrial buildings (paragraph 2.3.2), also examining best practices and reference works, especially regarding the adaptations and renovation of the building envelope.
Concurrently, the following paragraphs aims to define a reference framework for large and small scale interventions on industrial assets, focusing on the specific issues related to the types of building object of the study, considering functional adaptation, quality upgrade and aesthetic renovation that will be implemented for the case-study building in the last part of the present study.

2.3.1 Contemporary issues in the transformation of industrial heritage: adaptive reuse in the post-industrial era

The industrial wasteland has been presented through interesting views by many authors, which embraced its various definitions: from the concepts of 'terrain vague' and 'non places'[129], to the pragmatic denominations such as 'brownfields', 'territories of transition' and 'wastelands' or the evocative names 'contemporary ruins', 'fallow land' and 'industrial heritage' (Bertagna and Marini, 2011; Valle, 2014; Curulli, 2014).
Italy, as many other industrialised countries, is now facing a dramatic decline of industrial areas, also through natural processes, as a quite reactive response to the ‘destruction of the landscape’ seen over the last few decades (Paolini, 2009; Settis, 2010). In addition, the industrial architecture of the recent past is a vulnerable heritage, subject to obsolescence and lack of utility. But it is also an architectural heritage for which new initiatives and innovations can be promoted, for its transformation into meaningful elements, in its temporal-dimensions (conservation of the past, future reuse) and in its spatial-dimensions (new territorial models, renovation and upgrade of existing structures).

The debate on what should be preserved is answered, following the above considerations, in the different theoretical and practical approaches to the transformation of the industrial heritage, which have been developed over the past decades. On the one hand, the re-design of the territory must have as a reference the recognition of the overall value of its built heritage, on the other hand, the theme of technology plays a central role in the process of knowledge and recognition of the value of each building, both in its tangible and cultural connotations. In fact, having such a perspective in mind, the aim of the first phase of the study has been to identify the emergent cases of valuable industrial architecture constructed with precast concrete panels (chapter 1). In this sense, these remarkable industrial buildings represent not only an industrial heritage to protect but also potential centres for the re-design of suburban areas and landscape.
Moreover, as regards the focus of this study, the typological and constructive knowledge can orient the recognition of the value of the buildings and the selection of architectural works to protect. Since the factory also represents the place where the industrial revolution happened in its architectural aspects, even buildings of ‘minor architecture’ are often interesting, as an evidence of constructive and technological advances or symbolic and aesthetic values. Thus, the interpretation of the technological and typological evolution of the industrial building type enables the

[129] The concept of 'terrain vague' presented by Solà-Morales (1995) and the definition of 'non-place' introduce by Augé (1992).

identification of emergent architecture, such as buildings remarkable for the use of innovative industrial materials, for the structural conception, or as the works of prominent figures.

From the crisis of the industrial sector to a sustainable transformation of the industrial heritage

In general, the transition of developed countries to a post-industrial economy has made the transformation of spaces for production, at different scales (architectural, urban, and regional), one of the great cultural and architectural topics. The gradual change in the productive sector and the consequent change in industrial environments generate continuous need for actions to limit the loss of economic, cultural and identity values related to the production sites, in a process which aims to recognize, preserve and transform the built heritage and to favour socio-economic development of the territory. Thus the topic of the renovation of industrial buildings plays a key role in the current post-industrial dynamics, in which the abandonment of industrial sites is emerging as an important and distinctive process (Spaziante, 2008; Valle, 2014).

If initially the theme of the transformation of industrial areas was placed within the larger debate on decommissioning and reclamation, such as that between demolition or preservation, a growing focus on existing industrial buildings has emerged, as a more conservative approach to transformation, which implies a critical analysis of the potential, consistent with the concepts of ‘selective preservation’, ‘adaptive reuse’ and sustainability.

Policies and strategies, even in Italy, have been developed from these premises: on the one hand for the preservation of significant building of the industrial past, on the other hand for the redevelopment and regeneration of industrial areas in crisis.

In Europe, whereas the transformation of industrial areas involved wide urban spaces of major towns since the '70s, it finds nowadays a new dimension in the re-design of also suburban areas. Furthermore, while in the past decades the renovation works have involved major urban voids and ‘temples of work’, currently even areas and buildings with a smaller size and a less obsolete technological equipment are considered for intervention (Dansero *et al.*, 2003; Dansero and Vanolo, 2006; Spaziante, 2008).

Due to the growing de-industrialisation and abandonment in many countries, much research focuses on the future usefulness of many buildings and areas, which will no longer retain their productive function, and which might be difficult to reuse (Stratton, 2000; Edwards *et al.*, 2005; Berens, 2010; Couch *et al.*, 2011). This is also why the concept of post-production has promoted also different design approaches and trends: from the reuse (as recycling) of industrial buildings and landscapes (Filpa and Lenzi, 2014), to the idea of ‘negative capability’ of the environment (restraining urban sprawl), and interventions that pursue the complete desertion and real de-construction of industrial sites (Bertagna and Marini, 2011; Marini and De Matteis, 2014).

In the current approach to the transformation of industrial heritage, the issue of sustainability emerges in its physical-environmental and social-cultural implications and is addressed considering architectural, urban, cultural and environmental aspects linked to the reuse of industrial sites.

The actions of reuse and renovation of industrial heritage primarily correspond to a sustainable approach from the physical-environmental point of view, as they allow to retrieve a set of values: the value of the 'void', which is no more a waste of land but a resource (such as an opportunity to avoid land consumption through the reuse of brownfield or underutilized sites); the value of the networks and the existing infrastructure and their renovation for a system characterized by new uses and functions; the value of the industrial building and its reuse as recycling of architecture; the value of resources in an approach oriented to the life cycle of the building LCA (Life Cycle Assessment), or LCC (Life Cycle Cost). In this sense, a more specific interpretation of the elements of sustainability of the interventions on the industrial heritage is represented by the tools for assessment of the environmental sustainability of construction works, discussed in the previous chapters. These tools, which can also be applied to refurbishment projects[130], in their structure, suggest a series of assessment criteria and guide to some important issues.

As mentioned before, reuse and renovation of industrial heritage implies also the consideration of the aspects of sustainability in its social-cultural dimension, firstly in the selection of industrial buildings to preserve and restore due to their relevance: witnessing the ‘value of identity of a place and the productive vocation of a territory’, or the role as a ‘landmark of the industrial landscape’, or the architectural expression. In this sense, the renovation actions can be considered as gestures of restoration of the significance of a space, in order to preserve the continuity of the meanings from the traces of the past to the needs of the present[131].

The cultural element often corresponds to the socio-economic dimension, completing the framework of sustainability aspects, considering the renovation of the disused heritage as an attempt to make productive (again) urban physical assets and resources which, for their particular identity value, have a substantial fruition demand.

If environmental sustainability is clearly a key objective, the cultural sustainability can become the guidance element for choices, policies, territorial strategies, and design approaches, which characterise the transformation of industrial sites.

[130] The LEED certification can be used for existing buildings (LEED O+M Building Operations and Maintenance); the ITACA protocol gives specific instruction to be used for renovation projects.

[131] A comprehensive model for assessing the sustainability of the post-industrial transformation has been developed, for instance, by Ramello (2010) The model considers both social-cultural aspects and environmental issues, as summarised by Maspoli (2014).

Functional adaptation: new uses for industrial buildings, adaptive reuse, new manufacturing, and assessment criteria

The celebration of industry and its architectural products by the figures of the Modern Movement couldn't anticipate this impending shift in the western world from a manufacturing society to a service society, so that even industrial building which were once the works of a 'new spirit' have become relics of a bygone era (Schönwetter, 2015).

Due to the increasing awareness of the need to make optimal use of our spatial resources and concurrently protect our heritage, since the '60s, a variety of approaches for reuse (industrial) building have emerged. Contemporary issues concerning the ‘adaptive reuse’ of industrial buildings come, nowadays, from the same basic question (what should be done with industrial buildings?), considering their urbanistic potential, the functions that might be best suited for them, and the strategies and architectural concepts required to adapt them for new purposes.

A variety of way for reusing these spaces or building is possible and, as a result, the concept of adaptive reuse of industrial buildings has evolved, unfolding in the adaptation of old structures for new purposes according to the various architectural concepts and available technologies (Victoria, 2013).

While at settlement intervention scale there are various approaches for the reclamation of industrial areas, which range from the conversion to the ‘re-industrialisation’ (Marini and De Matteis, 2014), at the building scale the discussion on the future use of former industrial facilities have become increasingly complex.

To <u>determine the new function</u> for industrial spaces is crucial to chose the best fitting use for it, considering its features and its potential. The better suited the function is to the building, the less investment would be necessary to convert it, and in the case of listed buildings, the fewer alterations will be made to the building substance (Schönwetter, 2015). As a consequence, several studies propose the typological and constructive knowledge of the building as the first element for the assessment of the possible new use (Ramello, 2012; Vitale, 2013; Maspoli, 2014). The type of building, linked to the evolution of industrial architecture and settlement types (with their specific layouts, dimensional modules and structural grids), determines the costs for its conversion as well as its vocation to be reused (table 2-6).

This is why, for instance, the considerable width of the building and the height of ceilings might present challenges with regard to circulation, lighting, and building climatology, to meet the requirements for the new use. The <u>technological and constructional characteristics</u>, together with the state of conservation, greatly influence also the further design for energy and environmental upgrade of industrial buildings, including contemporary ones, outlining the criteria for the best application of current technologies.

building type	building system	vocation to reuse
Proto-industrial, usually single-body, tall serial building;	vertical structure in brick or stone masonry and interior bearing elements in cast iron;	tertiary and service sector or cultural use; adaptability depending on the load-bearing capacity of the floors.
Blocks with large central aisles or pillared halls;	brick masonry walls with vaulted floors; cast iron structures and brick walls; reinforced concrete skeleton system with brick walls;	important tertiary, commercial, educational or cultural use; adaptability influenced by degradation of structures.
Building types with high internal seriality, regular structural grid and multiple body;	brick masonry walls and saw-tooth roofs; reinforced concrete structures with brick or precast concrete walls;	possible use determined by the dimensions of the structural/functional grid.
Facilities and infrastructures for special productions on site (bridges, canopies, walkways, cranes, water towers, chimneys, silos, extraction towers);	mainly large metal engineering structures;	restoration and promotion as landmarks for industrial tourism at territorial level; securing, 'planned ruing' and 'naturalisation'.
Facilities and infrastructures for special productions off site;	metal engineering structures and machinery;	restoration as monuments for industrial tourism at urban or regional level.
Buildings for special productions (hydroelectric power plants, furnaces, steel industry, mills);	metal engineering structures with brick masonry or concrete walls;	restoration, connected to equipment, with partial or total musealisation and reconstruction of the production process.
Industrial archaeology parks; industrial facilities and other traces of production activities at regional scale;	parks including ruins; plants and infrastructures with engineering systems;	accessibility in relation to the level of remediation and safety; maintenance depending on the facility management level.

Table 2-6: vocation to reuse of different industrial site and building types (Maspoli, 2014)

A basic approach in conversion takes into account the space needed for the new functions and the forms of the area available in the former industrial building. This is why large industrial halls have been often converted into cultural facilities, such as theatres, concert halls or exhibition spaces, while smaller or more subdivided industrial spaces have usually found new use as commercial, educational or residential buildings (i.e. university campus or offices of social housing projects).
On the other hand, although programmes which imply a large number of smaller space might be less suited to industrial halls, some recent project of renovation of industrial building demonstrate how different function and space organisation can be created inside them. In this way, the existing substance and the outer shell can remain untouched, while the current safety and energy requirements can be reached more easily.
Nevertheless, industrial buildings, with their constructional and material features, favour many other considerations about the possibilities for their reuse and transformation, especially as related to their image and role. On the one hand, the 'temples of labour' often see a more conservative approach, which preserve their characteristic brick masonry or large concrete frames, and - intended primarily to cultural, commercial or service uses - may acquire the role of landmarks; on the other hand, serial building with typical shed roofing are suitable to a variety of uses and are converted through differently conservative or transformative solutions. In particular, the prefabricated industrial buildings, often subject of substantial modification, despite their spread and monotony, are in some cases remarkable examples of typological and architectural value and require interventions more attentive to preservation. In this sense, the investigation on the prevailing types and the architectural and environmental quality of industrial architecture, as discussed in the previous phases of the study, has provided a reference framework.

Furthermore, even though many studies and projects are examples of convincing conversion strategies, industrial structures hold potential for maintaining their original functions as well. In addition, not every industrial building can be adapted: some factories are custom-tailored to their original function, others are located in suburban areas far from the city services or require special strategies and policies. Moreover, criticism has recently arisen about projects of reuse that tend, due to the influence of globalisation, to transform any former ‘work-space’ into ‘leisure-spaces’, neglecting past values and potentially different vocations (Ciuffetti and Parisi, 2012).
For many areas, finding new productive uses seems a viable choice for other reasons: firstly, the evolution of productive processes and the new ways of working have made some old buildings suitable for new industrial functions; secondly, areas which cannot maintain their own industrial function as primary feature can be connected to wider territorial systems, pursuing a path of reorganisation of the territory based on renovation and valorisation of existing settlements (Dansero *et al.*, 2003; Bertagna and Marini, 2011). One chance is incorporating industries in compounds to be renovated, shifting away from conversion and promoting otherwise the functional

supplementing, maintaining the former manufacturing activities (Marini and De Matteis, 2014).

Moreover, reusing industrial buildings means also to design spaces that keep their link to the products. As the labour has changed along with its role in the society, the spaces for new manufacture and material production are today much different from those of the industry of the past (Marsh, 2012; Aitchison, 2014). In this sense, the place where people work have changed too, and yet in the '80s many authors have envisaged how the advent of new technologies and robotics would have radically subverted the - social an architectural - idea of the factory (Marsh, 1982; Nardi, 1986).
On the other hand, the adaptive reuse process can re-evaluate abandoned property assets and, at the same time, promote new urban and local dynamics oriented to attract creative initiatives. This is why, as part of this approach, nowadays each project of reuse tends to freely reinterpret the former industrial space, paying however particular attention to the new forms of work and the combination of their needs with the vocation of each industrial building. This evolution of the work towards new issues, such as co-working, condos of enterprises, shared-spaces and start-up companies, new-manufacturing, new hand-craft and makers (Sennett, 2009; Micelli, 2012; Gauntlett, 2013), digital districts and creative industries, otherwise declined, highlights how the abandoned industrial buildings are especially appropriate for renovation projects which have both symbolic and practical meanings. This scenario therefore results in workplaces characterised by a new connection with the territory and by a smaller scale, far too different from that of the twentieth century industry, with widespread and composite forms, fragmented but at the same time more integrated with other functions, but much more visible and permeable to public space than traditional factories.
Recent initiatives has drawn attention to the possibility of chose new temporary uses for former industrial spaces (Inti *et al.*, 2014), which appears a particularly suitable way to combine current economic and social needs, vocation of the buildings and planning restrictions.

Many authors have dealt with the theme of adapting abandoned buildings in relation to various specific issues, often reporting a wide series of renovation and functional conversion experiences and coming to envision and discuss the criteria to be considered for the functional adaptation of existing buildings, which generally include physical, economic, and technological aspects. Relevant research studies on the adaptability to reuse of buildings tend to consider: physical aspects, such as the structural integrity, the material durability, maintainability, design complexity; functional aspects: such as flexibility, disassembly, spatial flow, convertibility, structural grid, service ducts and organisation; technological features such as orientation, solar access, shading, glazing, insulation, natural lighting, natural ventilation, building management systems; quality standard such as occupational health and safety, fire protection, disability access, security, comfort, acoustics, indoor environmental quality, energy rating, standard of finish[132].

This highlights how the reuse process implies a multidisciplinary and multricriteria approach and, in fact, many studies propose models for assessing reuse potential as supporting tools for decision makers (sometimes included in decision support systems DSS) to make appropriate choices about the cultural, functional, technological and environmental aspects connected to the renovation[133].

In this sense, disused industrial buildings, in particular those of more recent construction (built after the '50s), generally show a good reuse potential according to their characteristic, such as structural types, designed to bear high loads, prefabricated building components, which can be easily removed and/or integrated, wide and high spaces, extended glass surfaces, which can ensure good lighting and natural ventilation, and accessory structures such as utility rooms, silos, tanks, usable in energy efficiency strategies (Donnarumma, 2015).

Furthermore, also methodologies such as post occupancy evaluation (POE) proved to be very useful to assess the new use of converted industrial buildings (Mundo-Hernandez, 2015). The process usually involves historical research, analysis of the conversion strategy, walkthrough investigation, and interviews, and in the end gives an important feedback on the user's perception of the reuse strategies.

The debate on the adaptive reuse of industrial spaces does not, however, end with the functional and technological aspects and involves aesthetic and architectural consideration as well. Recent literature offer a critical view of the design for reuse and sustainable place-making of derelict and underestimate industrial areas, providing a conceptual framework on the transformation of the post-industrial sites through both theoretical dissertations and examples (Stratton, 2000; Kirkwood, 2001; Berens, 2010; Douet, 2012; Curulli, 2014; Schönwetter, 2015; Mieg and Oevermann, 2015). The reuse of former industrial areas is sometimes discussed focusing on the ‘remaking’ as a new design approach, which goes beyond preservation and restoration and involves ‘alterations’ and architectural experimentation.

While the cultural values of the industrial heritage could be preserved and promoted through the conservation of memory of the industrial past, architectural features and values might be less easily identified and understood. An interesting view on the aesthetics of industrial architecture was depicted also by other disciplines, referring to the concepts of sublime[134], ugliness and ornament[135]. On the one hand the

[132] An exhaustive literature review on the topic is presented in the recent studies (Conejos *et al.*, 2011).

[133] A model for assessing reuse potential which appears particularly pertinent to the present study, being intended primarily for 'recent' industrial buildings, was developed by Donnarumma (2016).

[134] Besides the many possible considerations about the aesthetic design values in industrial architecture, the interesting association of the concept of sublime to industrial building is introduced and explained by Curulli (2014) Other interesting views on the aesthetic of industrial architecture.

overwhelming size of factories, the repetition of blocks, the endless extension of façades, with reiteration of windows and uniformity of materials, determine the building appraisal as an 'industrial monument'[136]. On the other hand, industrial buildings are often associated to ugliness, un-healthiness and hazard[137]. Thus aesthetics and the unique architectural characteristic of industrial architecture could be the key elements for the redesign process, which might give exceptional aestheticohal significance to the building or introduce cultural references for the building to be understood.

Furthermore, « [...] in industrial buildings ornament is to be found in the inseparable relationship between construction system and industrial building type. Therefore, ornament is embedded in the process of construction and growth of the building and emerges from the material of which the building is made. It is 'constructed decoration' rather than 'decorated construction' as in the definition of architecture by Auguste Perret» (Curulli, 2014).

In this sense, industrial buildings from the late twentieth century might be interpreted as ‘archaeologies of contemporary past’, in which the ornament represent still a remarkable features to protect, as the "mechanism for architecture to become connected to culture" (Moussavi and Kubo, 2006).

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[135] A relevant reference framework on the function of form and ornament in architecture presented in the recent publications by Moussavi at Harvard University Graduate School of Design (Moussavi and Kubo, 2006; Moussavi, 2009).

[136] This vision is well-illustrated by many relevant photographic projects dedicated to industrial architecture in the last decades, which sometimes presented systematic documentation, such as the Becher's large body of work, (Becher and Becher, 2004) and some sections of the reconnaissance programme carried out in France in the '80s *DATAR Mission Photographique* (missionphoto.datar.gouv.fr), or, in the Italian context, by Gabriele Basilico’s photographic survey on factories in Milan (Basilico, 1981), or, on the other hand, introduced alternative visions in recent exhibitions (Giloy-Hirtz, 2014).

[137] The idea of the factory and the manufacturing site as an hazardous and negative element of the industrial landscape is depicted especially clearly, for the Italian context, in the film Deserto Rosso (1964) by Michelangelo Antonioni, which also includes images of the SAROM and ANIC chemical plant (now abandoned) in Ravenna and the SADE power plant designed by Ignazio Gardella (1957-60) and now renovated.

2.3.2 Design concepts for the adaptive reuse of industrial buildings and best practices

In a context of economic crisis, industrial buildings are more and more often the subject of conversion, through adaptive reuse and refurbishment, in a perspective of sustainable transformation, which is consistent with values, restrictions, specific issues and new requirements. In recent decades, the flux of economic dynamics and the phenomenon of abandonment have directed studies and research on the themes of conservation and transformation of the industrial heritage and promoted the stemming of initiatives and projects for the renovation and the reuse of manufacturing buildings.
So, nowadays, industrial buildings from different historical age and geographical areas are subject to transformation; they are industrial archaeology monuments, sometimes forgotten, as well as contemporary workplaces, recently abandoned (F. 2-39 to F. 2-45). These large manufacturing spaces, made with the traditional building systems for industry - according to different ages - represent a significant sample of the building stock of industrialised countries - and especially of the Italian landscape, which requires reuse, upgrade and refurbishment, considering cultural values and architectural features as well as functional, structural, and environmental aspects.

Following the previous investigative phases of the research, concerning the documentation and the assessment of the architectural and environmental quality of the industrial building stock (chapter 1 and 2), the last section of the study face the technological aspects involved in the transformation of industrial spaces. Much research carried out in the Italian field has highlighted the link between the typological and technological knowledge and the strategies of reusing (Vitale, 2012; Vitale, 2013) and upgrading industrial buildings (Ferrante, 2008; Bassi, 2008; Bucci and Mollo, 2010; Sanchini and Bertoli, 2014). The industrial spaces are often, indeed, 'industrial products' and constitute, as a whole, a serial heritage, characterised by similar types, materials and construction techniques. A synthesis of the adaptive reuse and the retrofit solutions, however the result of project careful to the context and the architectural work, provides a useful interpretive key of the current background.

<u>Design approaches to the reuse of industrial building</u> have developed, during the last decades, considering some key concepts. On the one hand, some industrial building types, such as large silos and gasometers, favour an approach of the 'empty container', which tends to preserve the existing structures filling them with the new uses. On the other hand, other building types characterised by regular structural grid or high repetition of volumes promote the idea of the addition of blocks and extensions (Sposito, 2012).

However, functional and spatial flexibility appears to be one of fundamental themes in the current approach to adaptive reuse of industrial spaces, meant as adaptability in time and ability of the space to respond also to unforeseen need for transformation. In this sense, also the idea of unfinished work is embraced by many projects, which avoid the complete definition of the new setting and otherwise leave some space unresolved for further provisions.
The modification of the building emerges as an architectural theme and strategy towards the existing substance, which might include alterations, additions, and replacement, at various levels and scale.
Furthermore, the role of the surrounding context arises as related to the building both from the outside, in the definition of outdoor areas, paths and new relations within the site, the urban settlements and the landscape, and from the inside, as an indoor resonance of what happens in the 'outside world'.

The reuse of industrial building: consideration about best practices and reference works

In this context, a prime reference is the reclamation of wide industrial areas of Europe, which reveals that different approaches can coexist. This is the case with the area of the Ruhr, which, from the ’80s, was redesigned, beginning with a large intervention on the landscape and continuing with new constructions and the conservation and reuse of several valuable industrial buildings (F. 2-46)[138]. A similar approach was later adopted for the redevelopment of the Parco Dora industrial park in Turin, in which a number of ruins of industrial building were maintained following the principle of 'selective preservation' (F. 2-47)[139].
Following Europe examples, many Italian projects for the reclamation of industrial areas have focused on the reuse of abandoned areas through the realisation of new residential and commercial settlements or cultural spaces (Bondonio, 2005; Sposito, 2012). On the other hand, several areas in northern Italy have followed a different approach, with conservation of the productive function being combined with the creation of new functions.
At the same time, many industrial districts in northern Italy are developing specific strategies to pursue sustainability in their areas (Fontanin *et al.*, 2008; Cinotto and Ferrero, 2009), following recently established standards. The majority of them involve both the re-organisation of industrial processes and the refurbishment of the built environment, and concern: interventions to improve green natural landscape;

[138] The process of redevelopment of the Ruhr mining site is illustrated, among many other publication, by Marchigiani (2005).

[139] The case of the Dora industrial park is presented in Maspoli and Spaziante (2012).

concentration of the built environment and better organisation of the building plants, containing sprawl and avoiding interstitial spaces by favouring spatial continuity within green areas; optimisation of mobility and transport links; and provision of communal facilities.

Great opportunities have also arisen for specific small scale interventions on industrial architecture, following the principles of refurbishment and valorisation of buildings and their connections with the surroundings (F. 2-48; F. 2-49).
Several cases of reuse and renovation of industrial buildings, in Europe, favour the interpretation of 'sustainable transformation' of the industrial heritage. The transmission of values has been often the reason and guiding principle for design choices. In fact, even in the monuments of industry of the recent past we can read the evolution and history of construction techniques and aesthetics, in addition to the values of industrial culture and work history (F. 2-50; F. 2-51). Thus, a significant case for the present work turned out to be the concrete buildings from the last century, such as large 'concrete cathedrals' or even the more common prefabricated buildings. Many of these buildings have been subject, in recent decades, to abandonment and neglect or are located in industrial areas in decline. They have therefore been target of proposals and actions to give them a new role and identity, besides different functional and architectural outcomes, also as landmarks (physical and cultural) of a redesigned territory.
This idea is well-illustrated by the reuse process of several large concrete structure for industrial use in Europe, such as the SACM Fonderie and FRAC buildings in France, the NINO-Hochbau in Germany, the Ensidesa site in Spain.
The main building of the Foundries of SACM, in Mulhouse (France), was built in 1922 (Paul Maroseau), being an example of concrete industrial heritage of the last century and today a monumental space with a rich history. The conversion of the industrial complex involved the renovation and conversion of the main building as part of the new university campus (Mongiello & Plisson, 2003-2007). The original structures (especially the wide arches in r.c.) and plan organisation were preserved, while retrofit solutions were applied to the building envelope in order to achieve high standards of environmental quality - according to the standard HQE (F. 2-52; F. 2-53).
The building of the Niehues & Duetting company (known as NINO-Hochbau) was built in 1929 for the textile company in Nordhorn (Germany) and was permanently decommissioned in 1994. The restoration and reuse project (Rainer M. Kresing, 2008-2010) converted the building to an Excellence Center for Economy. The building is an example of functionalism in modern industrial construction, characterised by large frame structure in reinforced concrete, flat roof, and large windows. The restoration project included the preservation of the original image of the building and the maintenance of its exterior features (while the interiors were adapted to new uses). This industrial building, which at the time of its construction was already conceived as a focal point and landmark of the textile industrial site (also in terms of its extraordinary size), is still the largest building in the city and the main block of the new business park (F. 2-54; F. 2-55).

The AP2 building, a naval warehouse, was built in 1946 as a workshop of prefabrication for the ACF shipyards of Dunkirk (France) and closed in 1988. The building is both a place of memory and a geographic landmark, which characterise, now as in the past, the social history of the city and the region. It is one of the few emerging blocks lasting, after the decommissioning of the entire port area and the demolition of the surrounding buildings, and today still plays the role of landmark of the area. The project by Lacaton & Vassal Architectes (2009-2013) for the reuse as exhibition space for the FRAC Nord-Pas de Calais, also open to complementary uses. The size and the substance of the mass concrete structure of the AP2 building were highlighted by the operation of doubling the volumes through new transparent block. The strong identity of the industrial building was emphasised by the choice of keeping its original aesthetic, aged surface in fair-face concrete and plaster (F. 2-56; F. 2-57).
The *Parque de Bomberos* (fire station) of Avilès (Spain) is a remarkable example of industrial heritage from the late twentieth century (Juan Manuel Rodríguez Cárdenas, 1957-1958): the building, including a tower, is part of the large complex of former iron and steel industries of ENSIDESA and was included in the register of the Docomomo Iberico as a relevant architectural works for its compositional clarity and expressiveness of the construction elements (reinforced concrete structures, vaulted roof and skylights). While the rest of the industrial complex has been gradually converted, the building - although in a prime location and suitable for many functions connected to the new business park and the adjacent cultural centre, was left abandoned until 2009, when converted in *Parque Municipal de Servicios* (F. 2-58; F. 2-59).

On the other hand, focussing on industrial building types subject of the study, recent research reveal some trends in the reuse and <u>transformation of 'contemporary' industrial building stock</u> (Sassi *et al.*, 2007; Pignatti and Vallese, 2011; Bertagna *et al.*, 2012; Marini and De Matteis, 2014; Fabian *et al.*, 2015).
The research group RE-CYCLE Italy[140], in particular, has dedicated several activities (and publications) to the theme of recycling of industrial space. Studies and practices in different areas of the country show how the crisis of the productive sector of so-called 'industrial districts', has now left its indelible traces on the Italian territory. The ordinary assets of small and medium-sized enterprises (basically single-storey prefabricated building) consists mainly of recent constructions, broadly abandoned, disused or underused, or ever never used and in some cases never completed[141]. An

[140] National research programme, involving eleven universities, dedicated to the exploration and development of new cycles of life for spaces and elements of the city and the territory that have lost their use and sense. The series of publications produced within the programme is available online (<u>recycleitaly.iuav.it</u>).

[141] The substantial presence of abandoned ‘contemporary’ industrial buildings, as observed in the local context, was presented in Santi, Maria Vittoria and Movia, Alessia. 2015. *La dismissione industriale tra recupero e consumo di suolo: la resilienza di un territorio*, in Agribusiness Paesaggio & Ambiente, 18 (2015).

landscape of abandonment and waste (Bertagna and Marini, 2011), that recurs in every region and in every industrial areas district with images so similar and repetitive as the buildings of this type, in which the theme of 'recycling of the banal' stands out as an emerging issue (Battaino, 2012; Coccia and Gabbianelli, 2015; Lanzani *et al.*, 2016). Beyond programmes for the conversion and redevelopment of industrial areas in crisis, these industrial buildings of the SMEs are the subject of continuing operations of 'spontaneous recycling', which designated them to continuously new uses, sometimes totally unedited from their former vocation: thus these buildings become spaces intensively used by the new 'makers', or otherwise places for leisure activities such as gyms, dance halls, discotheques, game rooms and entertainment spaces (Fabian *et al.*, 2015).

The transformation of the contemporary manufacturing buildings faces many issues related to their typological and technological features, such as the building scale and a basic and bare construction, made with elementary systems and simple technologies (inspired by cost-effectiveness criteria). The great spans and free interior space - the absence of pillars or other structural elements - are the most relevant features of this building type while, in most cases, the building envelope rarely show elements of interest and characterisation (F. 2-45). This is why the solution for recycling and reusing these contemporary industrial buildings, especially the large structures made with the use of precast concrete elements, follow some general trends - as shown by many examples. On the one hand, some design approaches adopt what is called a 'wrapping strategy', covering the building with new functional layers, inside and outside; this solution might involve structural analysis and upgrade, energy retrofit and new aesthetic and formal connotation. Some other approaches opt for a 'inside strategy', including new lightweight structures and autonomous / self-supporting functional modules within the existing space. Finally, some solutions, pursuing the higher level of transformability and design experimentation, implement a 'naked strategy', with the removal of all the complementary system, as much as allowed by the building techniques (dry construction or prefabricated components), and the conservation of the bare structure of the building (Ruggiero, 2015).

The building envelope in the reuse and transformation of industrial buildings

The building envelope is a decisive element in the process of renovation - functional, aesthetical and environmental - of industrial buildings. The possible strategies for its transformation and upgrade, related to the reuse targets, reveal a structured framework of options, which includes altering, remodelling, recladding and refurbishing (Yudelson, 2010; Penoyre&Prasad, 2014). This is why the design approaches and the technological solutions, observed in the best practices of reuse of industrial architecture, are the basis for the critical analysis of these strategies (F. 2-60 to F. 2-79).

The reuse of industrial spaces implies the choice of the future use, according to criteria for adaptive reuse on the territorial and architectural scale, and, however, the refurbishment of the building, which must fulfil current requirements. More specifically, in a performance perspective, the interventions on (industrial) buildings are meant as technological solutions necessary to meet certain requirements, defined according to the users' needs for safety, well-being, usability, appearance, management, integration and environmental protection. The reuse approach implies therefore specific strategies for the functional-spatial redesign, the structural repair, and the energy performance upgrade.

With regard to functionality and usability of spaces, the projects for reusing and renovating the industrial heritage tend to freely reinterpret the original spatial layout of the building, according to the structural grid: various design solutions adapt the space to the new functions and ensure current accessibility and safety standards. The new functions are arranged to enable flexibility and integration, according to the emerging new forms of work (start-up, makers, creative industries), following the principle of fragmentation, in some cases, or the concept of open-space and sharing, in others. This is why various recent reuses have involved the addition of free-standing modules inside the former industrial space, in order to achieve an adequate performance level or for temporary uses (e.g. Tecnopolo in Reggio Emilia, Redbull Music Academy in Madrid, Z-Gallery in Shenzen); on the contrary, in other projects, to optimize the use of wide industrial spaces, the intervention focuses on restoring the functionality of the original building envelope (e.g. BASE in Milan, MedialabPrado in Madrid, Quicksilver showroom in Monaco).

The building envelope, providing the fulfilment of the above-mentioned requirements, results to be the key element of the building renovation process, between conservation and transformation; the past and present qualities of the industrial building are condensed and expressed in the building skin: cultural, aesthetical-architectural, and energy-environmental quality.

The cultural aspect is realised in the preservation of memories and the emphasis of the symbolic features that favour the recognition of the building as industrial heritage.

The architectural quality is highlighted by the juxtaposition of new materials and elements with the existing substance, attentive to the visibility of former structures and materials of industrial building, made evident by the choice of compatible and distinguishable solutions or by the relationship of scale and volume between existing space and new construction.

Improving energy efficiency is, today, the most relevant factor in the technical and regulatory upgrade and it substantially characterises the environmental quality of the renovation actions (Yudelson, 2010). The energy and environmental quality of industrial buildings, another recurring topic for research and experimentation, implies specific attention to the building envelope, for both the design of additions and the upgrade of original elements. New claddings, integrations, and replacements of the façade/roof elements are today opportunities for applying new technological solutions, high-performance materials, and integrated renewable energy sources (Sposito, 2012). In accordance with this trend and the current standards and regulations on energy efficiency the solutions for refurbishing the building envelope have considerably developed, also towards a greater attention to the issue of environmental sustainability (as discussed in paragraph 2.2.3).

Moreover, the transformation of the 'monuments of work', which are losing their identity and visibility as well as their use, is an opportunity to restore their values and meanings (Curulli, 2014).
The building envelope, besides fulfilling the requirements, becomes a way to communicate the functional transformation. This is why the solid masonry walls of manufacture and industrial secrets are opened to the city and the territory with large windows and transparent surfaces, exhibiting the new uses or the new forms of work, while the wide roofs, meant as inclusive roofing for production and offices, are carved to create new open-air common spaces, once again through the use of contemporary material and technologies. As a case in point, solutions based on the use of glass are present in the most recent reuse projects, both as addition to the original façade (e.g. MACRO in Rome, MOCAK in Cracow, and Design Centre in Mirafiori) and as renewal or extension of volumes (e.g. La Fonderie in Mulhouse and FRAC in Dunkirk); solutions of preservation ad adaptation of original roofing structures are present in recent project as well (e.g. Tonsley MAB in Adelaide, la Halle Pajol in Paris, and BRIN 69 in Naples).

F. 2-39: industrial ruins of a former steel plant,. Udine (author, 2015)

F. 2-40: abandoned industrial building, former steel mill Bertoli, Udine (author, 2015)

F. 2-41: abandoned industrial building in the industrial site in Torviscosa (author, 2015)

F. 2-42: abandoned industrial building in the industrial site in Torviscosa (author, 2015)

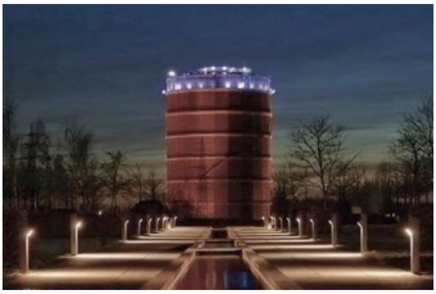
F. 2-43: abandoned industrial building, former printing factory, Udine (author, 2015)

F. 2-44: disused industrial building, Seleco plant, Pordenone (author, 2015)

F. 2-45: disused industrial buildings of small and medium-sized enterprises, Udine (author, 2015)

F. 2-46: Emscher Landscape Park, Duisburg, Ruhr area, DE, 1991-1999, Peter Latz *et al.* (lifeinpott.wordpress.com)

F. 2-47: Dora post-industrial park, Turin, 2007-2014, Peter Latz *et al.* (www.acomeambiente.org)



F. 2-48: Oberhausen Gasometer, former gas holder, converted in exhibition space in 1994 (www.oberhausen.de)

F. 2-49: Montemartini central, Rome, former power plant converted in museum from 1997 (author, 2014)

F. 2-50: Zollverein boiler house, 1928-1929, design Fritz Schupp and Martin Kremmer (Becher 1973)

F. 2-51: Zollverein former boiler house, Red Dot design museum, 1992-1997, Norman Foster (commons.wikimedia.org)

F. 2-52: La Fonderie, Mulhouse, FR, 1922, Paul Maroseau (www.mongiello-plisson.com)

F. 2-53: La Fonderie, Mulhouse, FR, 2003-2007, Mongiello & Plisson (www.dca-art.com)

F. 2-54: Nihues & Duetting NiNo Hochbau, Nordhorn, DE, middle '30s (www.nino-hochbau.de)

F. 2-55: Nihues & Duetting NiNo Hochbau, Nordhorn, DE, 2010, Rainer M. Kresing (commons.wikimedia.org)

F. 2-56: AP2 building, ACF shipyards, Dunkirk, FR, 1945 (www.communaute-urbaine-dunkerque.fr)

F. 2-57: FRAC Nord-Pas de Calais, Dunkerque, FR, 2014, Lacaton & Vassal (www.lacatonvassal.com)

F. 2-58: Parque de Bomberos (fire station), Avilès, ES, Juan Manuel Rodríguez Cárdenas, 1958 (www.arquitecturaeindustria.org)

F. 2-59: Parque Municipal de Servicios, Avilès, ES, Juan Manuel Rodríguez Cárdenas, 1958 (www.arquitecturaeindustria.org)

F. 2-60: Cockerill, Belgium, 2010 (phoenixgesellschaft.de)

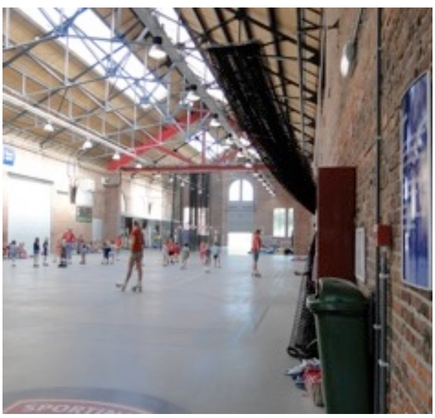
F. 2-61: MOCAK Schindler factory, Cracow, PL, 2010, Claudio Nardi (www.claudionardi.it)

F. 2-62: former Fiat Mirafiori, Turin, 2008, Isolarchitetti (www.isolarchitetti.it)

F. 2-63: BP factory, Florence, IT, 2000, Claudio Nardi (www.claudionardi.it)

F. 2-64: MACRO, former Peroni brewery, Rome, IT, 2010, Odile Decq (author, 2014)

F. 2-65: University campus, reuse of the former industrial complex in Bovisa, Milan (author, 2015)



F. 2-66: park Spoor Noord, Verdick&Verdickt architecten (www.divisare.com)

F. 2-67: Quiksilver showroom, Munich, DE, 2014, Clemens Bachmann (www.cbarchitekten.com)

F. 2-68: BRIN39, Napoli, IT, 2013, VulcanicaArchitettura (www.vulcanicaarchitettura.com)

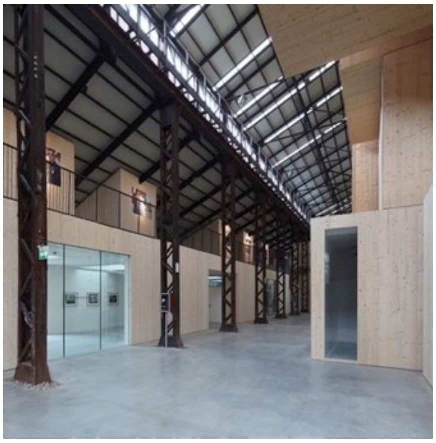
F. 2-69: Medialab Prado, Madrid, 2013 Langarita-Navarro Arquitectos (www.langarita-navarro.com)

F. 2-70: La Fonderie, Mulhouse, FR, 2003-2007, Mongiello & Plisson (www.la-fonderie.fr)

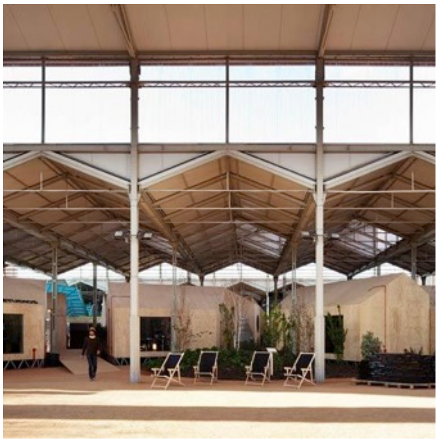
F. 2-71: Halle am Berghain, former power plant, Berlin, DE, 2013, studio Karhard (www.karhard.de)

F. 2-72: BASE A place for cultural progress, ex Ansaldo, Milan IT, 2016, Onsitestudio (www.onsitestudio.it)

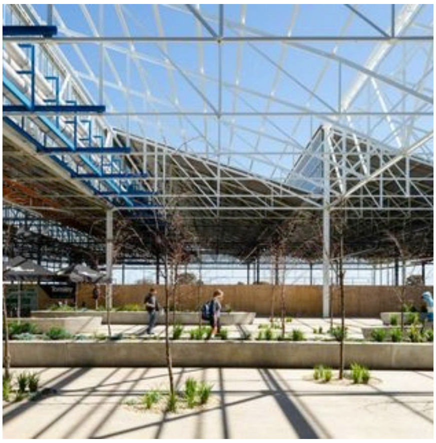
F. 2-73: Z Gallery, ex purification workshop, Shenzhen, China, 2014, O-OFFICE (www.o-officearch.com)



F. 2-74: Tecnopolo di ricerca, former Officine Reggiane, Reggio Emilia, IT, 2015, Andrea Oliva (www.cittaarchitettura.it)



F. 2-75: Redbull Music Academy, former warehouse, Madrid, ES, 2011, Langarita-Navarro Arquitectos (www.langarita-navarro.com)



F. 2-76: Tonsley Main Assembly Building and Pods, AU, 2015, Woods Bagot & Tridente Architects (www.woodsbagot.com)

F. 2-77: La Halle Pajol, Parigi, FR, 2013, Jourda Architectes (www.jourda-architectes.com)

F. 2-78: Tecnopolo di ricerca, ex Officine Reggiane, Reggio Emilia, IT, 2015, Andrea Oliva (www.cittaarchitettura.it)

F. 2-79: Citadel for Knowledge and Culture, ex Golinelli factory, Bologna, IT, 2015, Diverserighe studio (www.diverserighestudio.it)

3 THE TYPOLOGICAL TRANSFORMATION OF A PIECE OF INDUSTRIAL ARCHITECTURE THROUGH THE REDESIGN OF THE PANELS

3.1 Historical context: the architecture for Zanussi industries

As the physical places linked to the industry are now subject to a continuous lack of utility and conversion, an initial aspect to be taken into account was the functional one, considering the history of the industrial building and sites in their connection with the industry and the production activities that have taken place within them. The evolution of industrial architecture is intertwined with the industrial development of the second half of the century and, in this case, with the growth of the white goods sector in which the Zanussi industries were a prominent figure.

As was often the case for big Italian companies, the company's evolution was accompanied by the proliferation of new and up-to-date workplaces and production facilities, capable of attracting creative initiatives and becoming preferential fields for experimentation by designers and construction companies. The case of the successful cooperation between Zanussi with the architect Gino Valle led to interesting outcomes in industrial buildings like the Sèleco building, which now deserve protection and valorisation (paragraph 3.1.1).

A brief history of the last company to be housed in the building is illustrated, aiming to provide a synthetic timeline also as regards the use of this space (paragraph 3.1.2). This information is useful on the one hand for understanding what determined the size, the decline and finally the disuse of this industrial building, and, on the other, to keep in mind the industrial history of the site and promote a transformation process that pays it the respect it deserves.

3.1.1 The industrial buildings of Zanussi industries

A central element of the development of the industrial sites and facilities in the area of Pordenone were those companies that made the industrial history of the regional and local area. In this sense, the 'white goods' company Zanussi has played a key role in the evolution of the productive sector in Pordenone, being recognised as the heir to the tradition of the great cotton mills (Burello *et al.*, 2010) and resulting in the evolution of socio-economic dynamics as well as the evolution of the local area and its built environment.

In 1916 Antonio Zanussi (1890-1946) founded his company, the Fumisteria Antonio Zanussi, in a small workshop of 30 square meters on Corso Garibaldi in Pordenone (F. 3-1). The Rex brand was created in 1933 and in 1934 Antonio Zanussi built the first ‘real’ factory for Antonio Zanussi industries on its own land in via Montereale in Pordenone (F. 3-2); the building was of about 2,000 square meters and represented, in hindsight, the conjunction between the first small workshop and the great industrial plant of Porcia (Diemoz, 1984).
In the ‘50s, in fact, the transfer of the production activity from the site in Pordenone (Montereale street) to that of Porcia began, as the high production volumes required more space (Burello *et al.*, 2010), which was created in the new factory through construction phases which took several years and multiple actors. The development of the industrial area of Porcia began in 1951, through the efforts of Lino Zanussi and the then-mayor Antonini: the industrialist Gaetano Costa from Milan commissioned the IMES enamelling factory as the first industrial building of the first industrial area of the town, which then would then evolve into the Zanussi complex (F. 3-3). Only later, in fact, in 1954, did Lino Zanussi buy both the enamelling factory and the surrounding land[142], upon which the *Zanussi Cucine* plant for the production of white goods - refrigerators was built (Diemoz, 1984).
Concurrently, various production plant of Zanussi were placed in the industrial area of Vallenoncello, in the south area of Pordenone (Diemoz, 1984; Burello *et al.*, 2010): in 1956-1957 was created the IEMAT for the production of electrical components, vending machines and other accessories, and in the same year also the branch *Zanussi Grandi Cucine* - large kitchen appliances - moved to Vallenoncello, being established as an independent company and renamed *Zanussi Grandi Impianti* S.p.A.

In the period between the '50s and '60s which were characterised by the rationalisation of the production process in the Italian home appliances industry, the fruitful collaboration between the architect Gino Valle and Zanussi began (Gregotti, 1986): from 1956 he was involved as consultant for the industrial design, promoting the creation of a dedicated internal department, the Unit for Industrial Design or *Unità disegno industirale Rex-Zanussi*. From research into structures, forms, and modular coordination for white goods, the company came up with the original solutions and the appealing aesthetic style for which is renowned[143]. In the ‘60s, Valle and the Unit were also involved in the design of the new line of Zanussi brown goods - television sets.

The ‘60s were characterised by a strategy of diversification and expansion of the company, which also resulted in the increase of the production facilities - from eight in

[142] The industrial site was originally an area of about 400,000 square meters, later extended to 700.000 square meters.

[143] For the originality of the solutions, combining aesthetic, ease of use and technical innovation, the products devised by Zanussi several times won the "Compasso d'Oro" design prize.

1964 to ten in 1966 and thirteen in 1968 (Burello *et al.*, 2010). Beside the experience in industrial design, the collaboration between Valle with Zanussi Industries extended in those years to the field of prefabrication (Gregotti, 1986), leading to the construction of various buildings, from the completion of the plant in Porcia and the new plants in Vallenoncello, to other notable crations[144].

These industrial buildings programmes represented an opportunity to investigate the reproducibility of architecture and the new production processes based on prefabrication, which proved a particularly suitable solution for enabling further modifications and extensions resulting from production needs (Croset and Skansi, 2010).

In particular, as regards the collaboration between Gino Valle and the industry, Croset (2009) noted how he was «a pioneer of a radically new way to design with technical offices - internal to the company -, starting with his first jobs of the '50s for Solari and Zanussi. Valle liked to recall that he had begun with the design of the products, working as an external consultant for the technical office, before finally arriving at the architecture of the buildings, which was what really interested him».

In addition to the Zanussi offices (1961), the new buildings in the complex in Porcia were thus designed by Gino Valle: the large warehouses to house the various production activities of *Zanussi Cucine* (from 1963), and later the *Asse Attrezzato Zanussi* (the works canteen in 1966, the Diad offices in 1967, the staff offices in 1969, and also the reception building and the heating plant). In this phase, the production buildings already present since the '50s in the area of Porcia were progressively integrated with the new buildings, marking the transition from a building system in concrete and bricks and the industrial building type with vaulted roof to a lightweight system with steel structures and precast concrete cladding for buildings with shed roof.

Two new plants designed by Valle were also built in Vallenoncello: the *Zanussi Elettronica* building (1967-1969), for the production of brown goods - television sets -, which perfected the range of civil and industrial electronics products and eventually became the company Sèleco, and the *Zanussi Grandi Impianti* building (1968), which specialised in the large kitchen appliances sector (Diemoz, 1984). These two buildings were made using the same building system used in Porcia and with the use of the same - although differently sized - prefabricated elements.

In addition, a programme of regional and local subsidiaries for the storage and distribution of products by Zanussy was developed in that period and was followed by the project for the Rex-Zanussi model warehouse - the *Deposito tipo Rex-Zanussi* (1963) - by Gino Valle. The warehouses were built in various Italian provinces (Padua, Bergamo, Milan, Perugia, and Rome); they were entirely prefabricated and conceived of as 'anonymous' elements able to adapt to a range of surroundings - from the

[144] As confirmed by a recent review of Valle's works for Zanussi, in (Valle, 2016).

countryside to suburbs or industrial areas - according to the concept of 'planned invisibility' (Gregotti, 1986; Croset and Skansi, 2010).
During the '70s, the expansion of the company continued with the absorption of various Italian companies of the sector (Becchi, Stice, Castor, Zoppas, Triplex and Sole) and the construction of facilities for companies of the Zanussi group in different industrial areas of the region, such as the factory of television sets in Campoformido (1971) and the headquarters of *Zanussi Metallurgica* in Maniago in 1968-1971 (F. 3-4) - cited as a model site for metallurgical processes (Diemoz, 1984).
In the '80s the Zanussi group had significant real estate assets, including industrial sites built by the group or inherited with the acquisition of other companies, as reported in 1981 (Diemoz, 1984): facilities for the sector of white goods in Porcia (PN), Susegana (TV), Maniago (PN), Solaro (MI), Forlì, Badia a Settimo (FI), Chiusa S. Michele (TO), Bassano del Grappa (VI), Pomezia (roma), Logrono e Madrid (Spagna); facilities for the sector of brown goods in Vallenoncello (PN), Campoformido (UD), Orsenigo (CO), Panigale (BO), Pontinia (LT), Longarone (BL), Madrid (Spain); facilities for the sector of large kitchen appliances in Vallenoncello (PN), Conegliano (TV), Valbrembo (BG), Rovigo, Malo (VI), Madrid (Spain); facilities for the sector of components in Mel (BL), Maniago (PN), Rovigo, San Fior (TV), Oderzo (TV), Comina (PN), Mansuè (TV); facilities for small domestic appliances sector in Villotta di Chions (PN), Spilimbergo (UD), Rovigo, Sambuceto (CH).
In the '80s, the Electrolux business plan led to corporate downsizing and divestments, with the sale of several factories (1984-1985), including the Zanussi Elettronica building in Vallenoncello to Sèleco itself, which by then was already an autonomous company (Burello *et al.*, 2010).

This study has therefore also taken into account this widespread presence in the region of buildings related to Zanussi Industries: despite the scarce documentation of the projects and the processes that led to the construction of the various plants in the region after the '60s, these building are clearly recognizable due to their scale, type and architectural features, and especially as emerging examples in the industrial building landscape. This widespread and valuable presence has also directed our interest to the Sèleco building, which is one of the first buildings made for the company and which may be considered a basic model at the origin of the type, worthy of analysis and preservation.

3.1.2 The industrial site in Vallenoncello, from the Sèleco company to its current disuse.

Since the ‘80s the industrial plant in Vallenoncello has remained linked to Sèleco - the Italian company that made the history in the field of consumer electronics - and the events which took place through the various managements up to the current closure. Sèleco was founded in 1965 as a brand of Zanussi Elettronica S.p.A., the electronics division of the company Zanussi which since 1967 has had its headquarters in the site in Vallenoncello of Pordenone (F. 3-5). The boom in the market for televisions in those years allowed the Sèleco brand to rapidly gain a reputation for itself and numerous awards for the quality and the aesthetic of its products (F. 3-6)[145]. However, since then, the company has seen both moments of success and times of crisis, determined by the incessant changes of a dynamic market like that of consumer electronics, in which continuous technological innovations are necessary to deal with the many competitors.
In the '80s, with the crisis of Zanussi (sold to Electrolux in 1984), Sèleco became an autonomous electronics company, specialising in the production of colour televisions, under the name Sèleco S.p.A. - created as a joint venture, which included the same Zanussi, the public finance body REL and Indesit (Boni and Terasso, 1999). Since the majority of Italian manufacturers of television sets at that time were also struggling, Sèleco became the first company in the national industry, dominating much of the domestic market.
In the early 90s, Sèleco went on sale (1988) and was sold (1991) to Rossignol, an entrepreneur from Piedmont who became the CEO of the company (Boni and Terasso, 1999): in this period, with the increase in profits and production capacity and with the Elbe acquisition (1992), Sèleco was the fourth company in the industry in Europe. It was in the same year (1991) that the company acquired from the Brion family the Brionvega company, the brand already known for its original models created by famous Italian designers including Franco Albini, Marco Zanuso and Richard Sapper, and Mario Bellini.
In this period Sèleco counted, in addition to the plant in Vallenoncello, four production facilities: two in Italy (Milan and Airasca, Turin), one in Spain and one in Malta. The '90s also marked the beginning of the inexorable crisis of the company (F. 3-7): the first difficulties, due to loss of competitiveness on the market and the heavy costs of the investment made for the acquisition of Elbe and Brionvega, led to the Spanish plant’s closure (1993) and the risk the company closing down (1994); the attempt at recovery through a restructuring plan and recapitalization failed and the company

[145] A recent overview of the history and design of Sèleco tv set is presented, including interesting documentation from the company’s archive, in a recent Master degree Thesis (Tonini, 2007).

faced its first bankruptcy in 1997 (Boni and Terasso, 1999). Nevertheless, the Sèleco company and the trademarks associated with it were taken over in the bankruptcy proceedings (1998), with the foundation of a new company called Sèleco-Formenti S.p.A. (Cantons, 2011). The ownership then passed into the hands of people with long experience in the production of television sets, which led the production to LCD models and the revitalisation of the leading products of Brionvega (Doney, Algol, and CuboGlass).
In the 2000s the company faced a second crisis - mainly caused by the slump of prices in the market because of the overwhelming competitiveness of foreign products (Boni, 2010). While the first LCD products (Ego 15'') and new articles of the Brionvega brand (Doge by Mario Bellini) were being launched, these problems led the company to another winding-up phase (2004).
After two years of temporary receivership (2005 by Giovanni Formenti and 2006 by Francesco Fimmanò), Sèleco was taken over by the entrepreneurs Marco and Carlo Asquini in 2007 and changed its name to Super//Fluo S.p.A.: the acquisitive package included three historical brands of *made in Italy* television sets (Sèleco, Brionvega and Imperial) plus a number of less significant brands (Boni, 2010). With the new ownership and the reinstatement of many of the employees of the previous management, the company resumed production and returned to the market with some new products (e.g. the LCD TV model Bivio and the radio model ARADIO)[146]. In late 2008 Super//Fluo was stuck by new difficulties that led to its winding-up and the third bankruptcy (2009)[147].
In 2010 the former Sèleco was then sold to Selek-Technology of Calligaro, with the transfer of production from Vallenoncello to Villotta of Chions and the acquisition of the brands Sèleco, Imperial and Phonola by the new company. Meanwhile, Super//Fluo, retaining its own factory in Vallenoncello, returned to the market with new products as well as the previous producs, such as ARADIO, previously sold under the Sèleco brand. Nowadays, the plant in Vallenoncello is only partially used by the company, and houses the production and sales activities for the brands Super//Fluo and Brionvega, including a small showroom for the products.

As <u>the building is still underused</u>, various new uses have been suggested for the site in recent years. Among them, in 2006 an initial hypothesis proposed the creation, in the former Sèleco plant, of the new Technology Hub of Pordenone, which was also formalised with a preliminary contract for the purchase of part of the property; the project was also interesting from an urban planning point of view, proposing as it did

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[146] Information on the most recent Sèleco products on the website www.seleco.tv and www.super-fluo.com.

[147] The bankruptcy was referred to Smart TV, the company which had acquired the previous Sèleco-Formenti and only later became Super//Fluo.

the regeneration of a disused area destined to decay to create a kind of “citadel of research”, but was later abandoned[148].

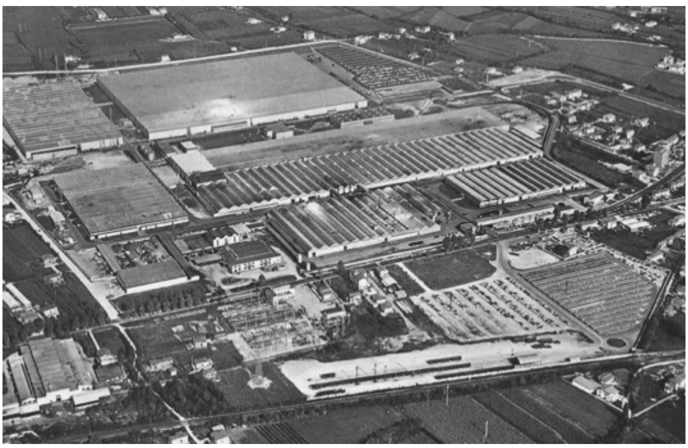
Since then the owner has been evaluating the possibilities of conversion of the production space of the former Sèleco, taking into account activities other than manufacturing and ranging from crafts services to management, catering, and the sale of goods made by the same companies, all complemented by accommodation, sports and recreation facilities. In this sense, the current planning instruments and regulations do not allow for the full inclusion of these intended uses in the industrial zones; comments were submitted to the new Town Plan of Pordenone, requesting to include in the list of the intended uses for the area also hospitality, catering, commercial and retail functions[149].

[148] The evolving discussion on the future use of the Sèleco site have been occasionally reported in local newspapers, such as several articles on Messaggero Veneto, 8th of March 2013 and 2nd of April 2014.

[149] The debate on the intended uses provided for many areas by the new Town Plan of Pordenone was originally presented in local newspapers too (Milia, 2016).

F. 3-1: Officina fumisteria Zanussi (www.zanussiprofessional.it)

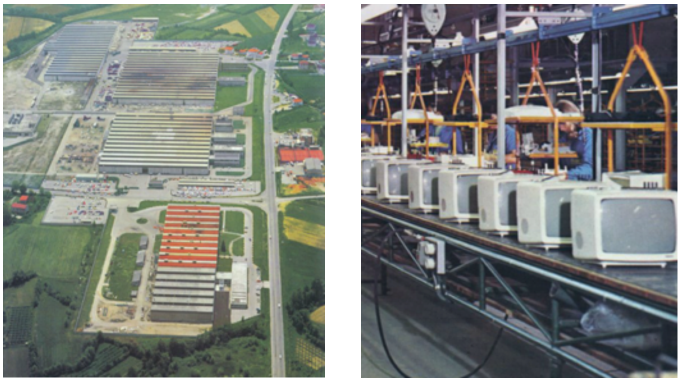
F. 3-2: Zanussi via Montereale 1934 (Bertani, 2016)



F. 3-3: Zanussi plant in Porcia in the '70s (www.delcampe.net)

F. 3-4: construction of the Zanussi plant in Maniago, Pordenone, in the '70s (www.zml.it)

F. 3-5: Sèleco plant in Vallenoncello in the ‘70s (Tonini, 2007)



F. 3-6: Sèleco and Brionvega TV set from the ’’70s and ‘80s, exhibition Elettro Domesticità, Pordenone November 2016 (author, 2016)

F. 3-7: Sèleco building in the '90s (messaggeroveneto.gelocal.it)

3.2 The Sèleco building: an 'architecture for the industry'

The Sèleco plant, built in the late '60s and designed by the architect Gino Valle for the company Zanussi, is a case in point in the past and present scenario of prefabricated architecture for the industry. As regards the topics addressed by the study, the former Sèleco building expresses and summarizes the characterising element of the Italian building tradition for industrial architecture, combining the design techniques and the building systems of precast concrete with an aesthetic and architectural approach oriented towards experimentation, modern architectural languages and the expression of the corporate identity through the workplace.

In the current changing context of the spaces linked to the industry, these aspects have, on the one hand, directed policies towards the protection, and, on the other, pointed out new issues regarding the reuse and transformation of buildings.

3.2.1 Analysis of the building, the original project and the current condition

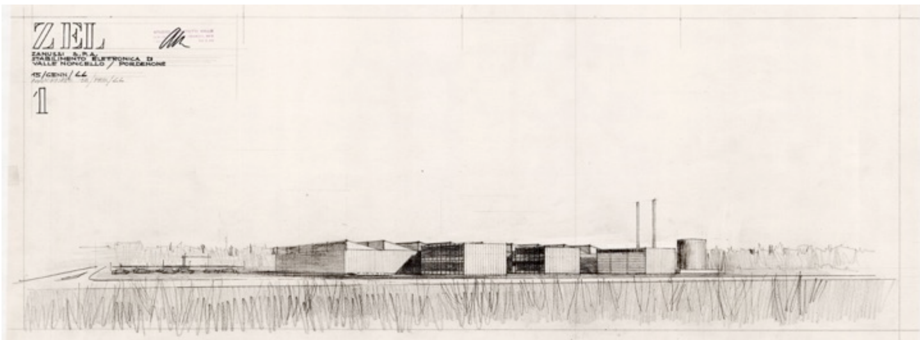
The Sèleco plant, designed in 1966 by the architect Gino Valle, was built within the industrial area of Pordenone in Vallenoncello to accommodate the production of Zanussi electronic products and later was intended to house the production of Sèleco and Brionvega television sets, including offices, showroom and services for these activities

The project for the Sèleco factory is still unpublished - and in fact was not included in the catalogues of works of the architect Gino Valle present in the relevant publications - and only in recent times has it once again become a subject of interest[150].

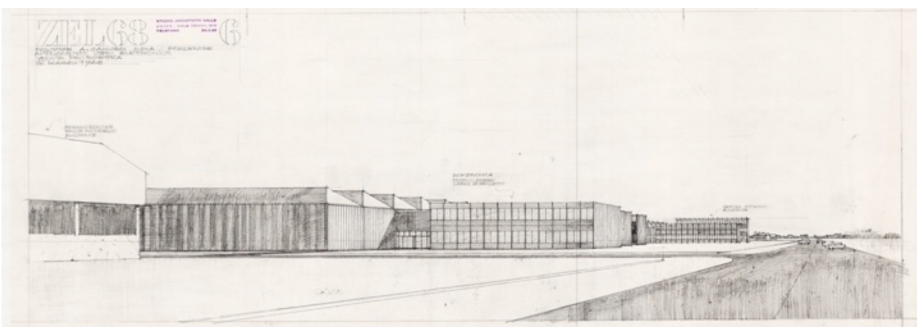
The documents archived in the municipal offices of Pordenone have confirmed the attribution to the author of the project; the search in the archives of Valle Architects allowed the recognition of the main phases of construction and development of the plant in the late '60s (F. 3-8 - F. 3-13). In particular, the drawings stored in the archives in the section on projects for Zanussi clearly illustrate the entire project in its

[150] The buildings of Sèleco, Sole and Zanussi Grandi Impianti - similar for the use of the same type of structure and cladding - have been included in the latest guide to twentieth century architecture in Pordenone (Baccichet *et al.*, 2016).

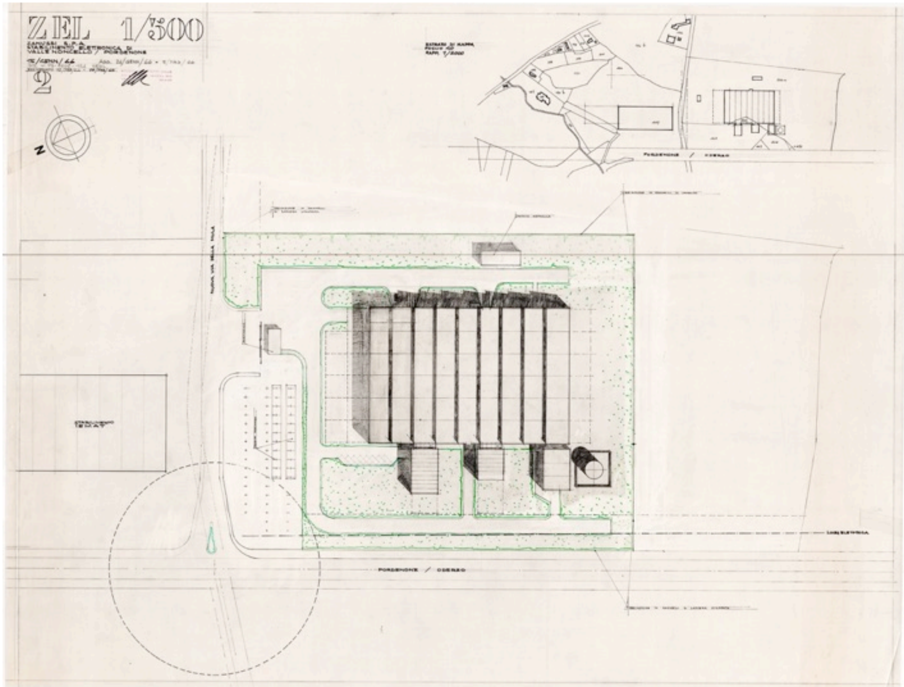
various phases, and allow the identification of the progressive alterations and extensions which have been made to the building over the last forty years.
The work of survey and redesign resulting from a series of field surveys and developments - which followed the identification of the building as an object of interest and possible reuse, refurbishment and transformation - is thus the first element for the comparison between the project and the current status of the building (F. 3-14 - F. 3-20) with the aim of its critical analysis.



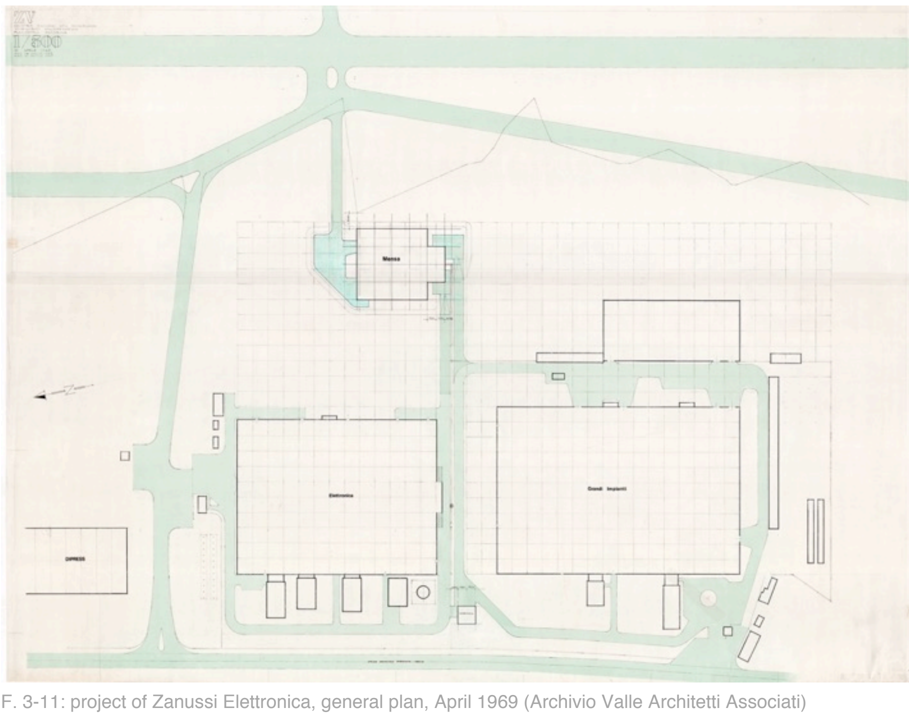
F. 3-8: project of Zanussi Elettronica, perspective, January 1966 (Archivio Valle Architetti Associati)



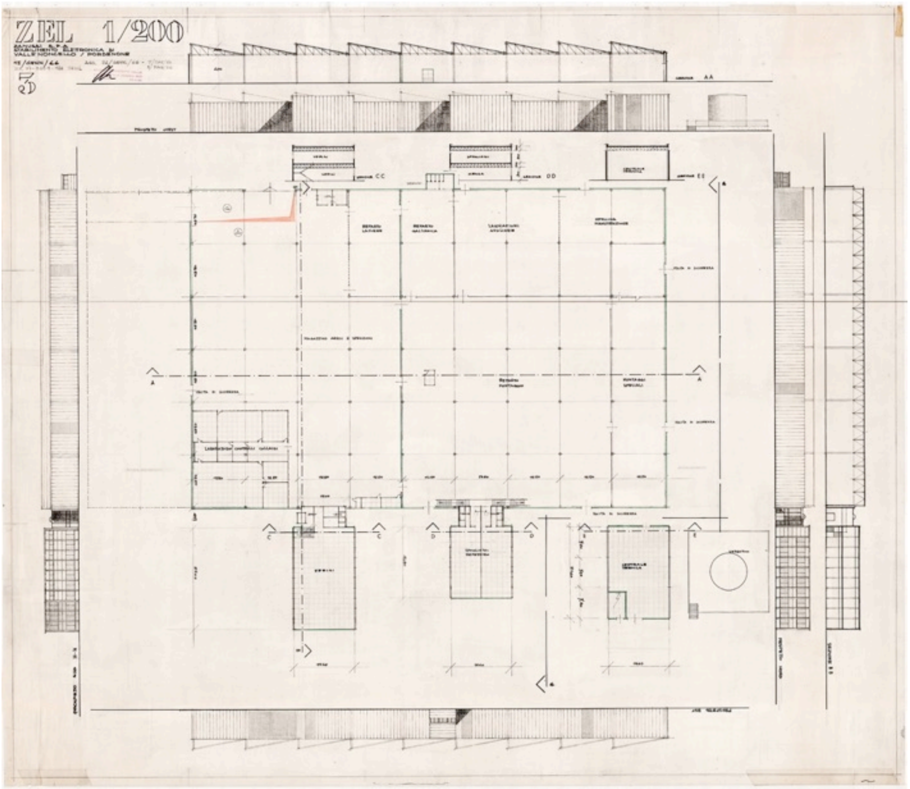
F. 3-9: project of Zanussi Elettronica, extension of the office buildings, perspective, March 1968 (Archivio Valle Architetti Associati)



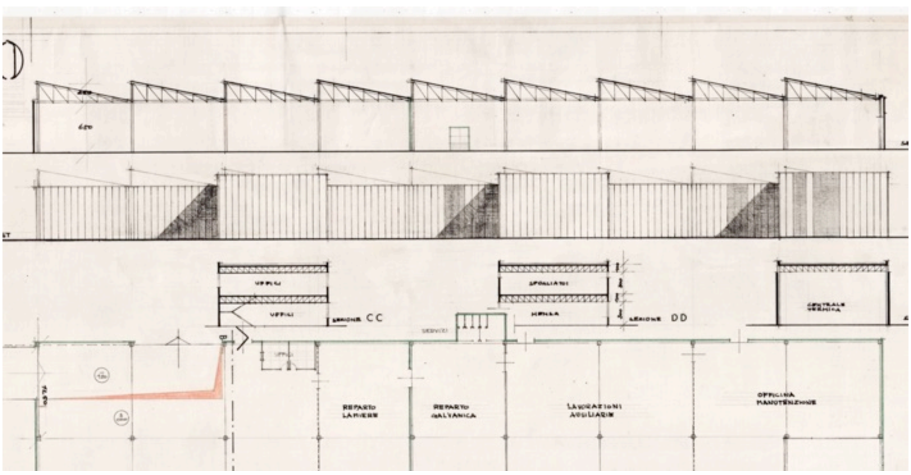
F. 3-10: project of Zanussi Elettronica, general plan, May 1966 (Archivio Valle Architetti Associati)



F. 3-11: project of Zanussi Elettronica, general plan, April 1969 (Archivio Valle Architetti Associati)



F. 3-12: project of Zanussi Elettronica, plan, sections and elevations, January 1966 (Archivio Valle Architetti Associati)



F. 3-13: detail from the project of Zanussi Elettronica, plan, sections and elevations, January 1966 (Archivio Valle Architetti Associati)

The analysis of the documentation reveals a series of significant phases of design and construction of the Sèleco plant.

The first version of the project, dated 1966 (drawings 1-2-3 and 7-8-10), proposed a plant of much smaller dimensions than the one currently present: the single-storey warehouse for the production was organised in a 6 bays by 9 bays plan and the protruding blocks were only 3 two-storey buildings, two of which for the offices and one for the thermal power plant.
The project was updated in a second version in 1968, consisting of the expansion of the electronic offices with the addition of a fourth protruding block of the same type, also two-storey, and connected to the adjacent office block through an entrance hall (detailed in the drawings 6-7-8 of 1968).
The general plan of the site, updated in 1969 (after the completion of the construction), shows the organization of the site in Vallenoncello, with the two factories of *Zanussi Elettronica* and *Zanussi Grandi Impianti* and a works canteen. The area was organized with green spaces and external routes that allowed access from the surrounding road network and connection between the buildings; the Zanussi works canteen, for instance, could be reached from both plants. While access to the *Zanussi Grandi Impianti* was possible directly from the main road (Pordenone-Oderzo), the main access to the *Zanussi Elettornica* was organised through a crossroads (next to the Dipress plant), passing a small gatehouse (included in another drawing) to the north of the building; the external routes system allowed direct access, vehicular or pedestrian, to the building from the four sides, according to the organization of the production departments. In this version the *Zanussi Elettronica* building (later known as Sèleco) is of greater dimensions than in the first project, 13 bays long and 10 bays wide - a subsequent development of the project probably led to the final realisation of 13 x 12 bays -, while the protruding office buildings were, as now, four.

The plant underwent its first major modifications between the ‘80s and the ‘90s [151]: three of the protruding buildings (offices and canteen-dressing room) were renovated as designed by the architect Dell'Agnolo; the objective of the intervention was mainly to improve energy efficiency through the recladding of the north and south façades with the addition of an insulating layer and a new cladding in prefabricated r.c. panels (vertical, contrary to the original), the correction of thermal bridges through the covering of the steel pillars, the replacement of windows and the replacement of the floating floors and ceilings, integrating the necessary fittings and wiring.
In the same years, the main building - the production department - was also subject to adaptations: the original concrete floor (with addition of iron powder for increased

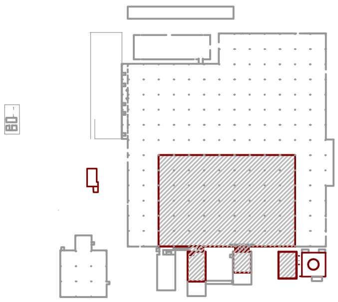
[151] The work on to the buildings from the ‘80s were reported by Renzo Vitulo, former employee of Sèleco and now superintendant of the site, during a field survey and interview carried out on 24th March 2015.

strength) was covered with a layer of anti-static coating; a number of pillars were covered in order to conceal fittings and wiring.

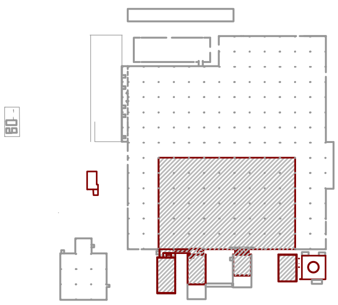
In the ‘90s (1997), to fit new production needs, the main building was extended in the rear part (the east front) to create an additional volume for the storage of the Sèleco products[152]; a bay and a platform for loading and unloading and an inflatable storage dome were also added on the north side of the building.
The extension consisted in the addition of 2 aisles for half the width of the building (adding up to a total size of 13 x 14 bays), through the demolition of part of the existing east façade. The design of the new space took into account the original structural elements (metal trusses and pillars), while the cladding was realised with new prefabricated panels in prestressed r.c, horizontally laid and of 250 cm width.
In the 2000s, to meet the requirements of compartmentalisation in compliance with fire protection, the internal space was subdivided through 120 REI partitions made of r.c. blocks. In the late 2000s, following the transformation of the storage part of the warehouse into a production department, the skylights of the east front were darkened by the addition of polycarbonate panels.
Between 2015 and 2016 the roof cover in corrugated aluminium sheet was renovated and secured.

[152] The extension was designed by an architectural firm close to the family Formenti, then owner of the facility.

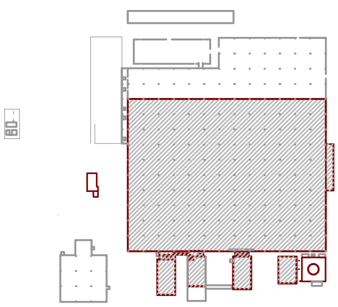
DESIGN PHASES



1966

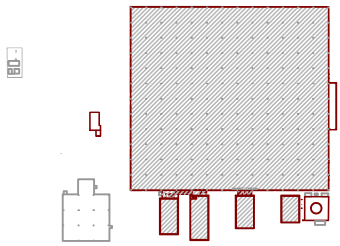


1968

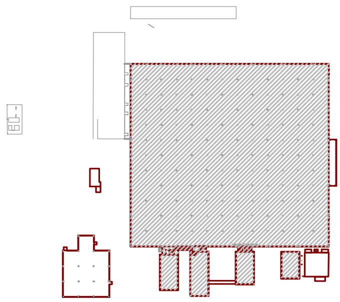


1969

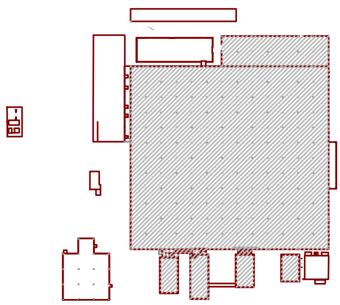
CONSTRUCTION PHASES



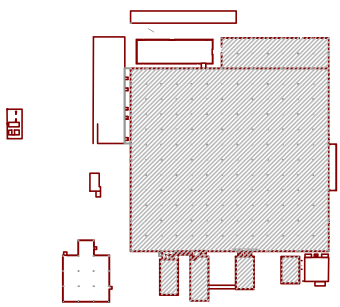
1969



late '80s

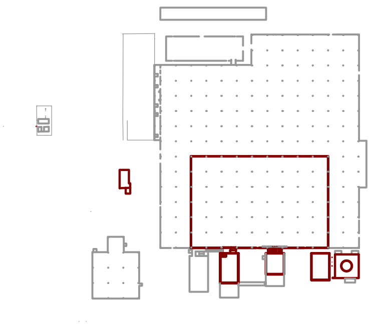


late '90s

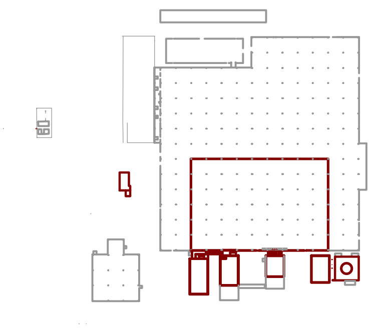


2014

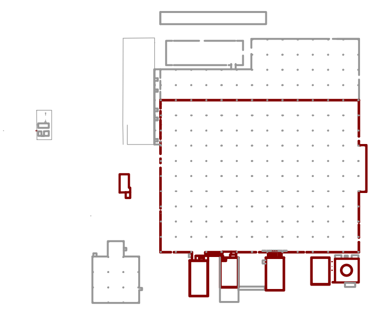
DESIGN PHASES



1966

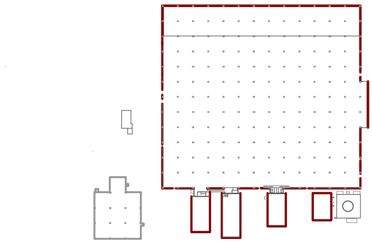


1968

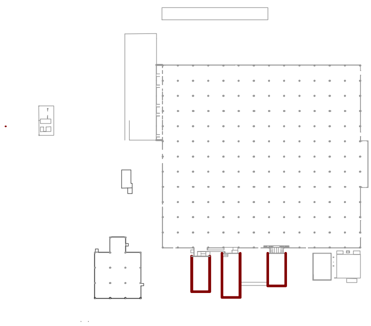


1969

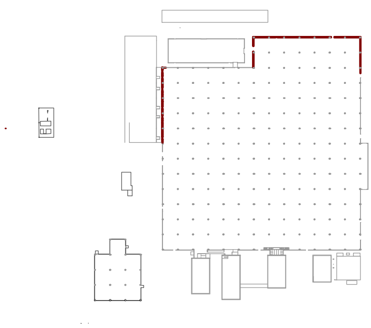
BUILDING ENVELOPE ADAPTATIONS



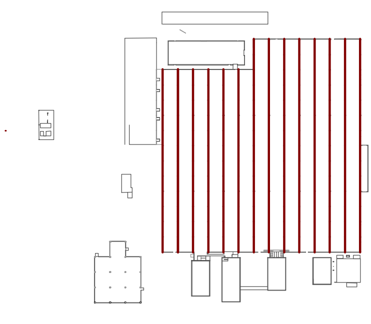
1969



late '80s



late '90s



2014

The complex consists in two types of block: the main production area, which is a parallelepiped with a shed-type roof, and the offices buildings, which protrude from the main section of the factory. “This organisation of the blocks, with respect to the nearby road, was deliberately chosen to accentuate the appearance of the office buildings, underlining a separation, both physical and functional, from the main production area” (Baccichet *et al.*, 2016). This functional solution serves also to reduce the visual impact of the vast factory building, according to a recurring topic of study in the work of Gino Valle: the relationship between landscape, infrastructure and industrial buildings (Croset, 2009). In fact, later, in several projects from the '70 (Dapres, Bergamin), Valle applied a similar concept using colour in order to change the perception of the industrial building, which was intended to be seen from the nearby roads or highways more as a ‘sculpture’ than as architecture.
Using the same construction approach, and for the same company, between 1966 and 1968, Gino Valle also designed the *Zanussi Grandi Impianti* in the adjacent lot, and the SOLE plant (known as DIELM) in the Comina area. Characterised by a similar functional layout, with protruding blocks and the same building elements, especially the wall panels, the three buildings appear identical in terms both of form and functions.

Functions: The production area is entirely arranged in the single storey main building, in which the production lines are organised in line with the shed-roof to allow the maximum dayligh[153]t of the workstations. The administrative and service area consists of four two-storey blocks: the two office blocks, connected to the main building through a passage which serves as the entrance to the plant, the block for the changing-rooms and the works canteen, which is linked to the production area by restrooms and showers, and the heating plant, which is detached from the main structure. Some more recent structures are also part of the complex: the bay and platform for loading and unloading, the inflatable storage dome, the accounting office, the new reception, the waste warehouse and some additional technical spaces (fuel storage, electric generator, etc.).

The outdoor space is organised into green areas and circulation patterns, with several internal access roads and pedestrian paths and entrances, in accordance with the original project.

[153] Floor area for each span of about 150 m^2 and glazing area 21.8 m^2, resulting in a glazing ratio of 1.5/8 which comply with the regulation.

F. 3-14: North view of the Seleco building (2016)

F. 3-15: West view of the Seleco building (2016)

F. 3-16: East view of the Seleco building (2016)

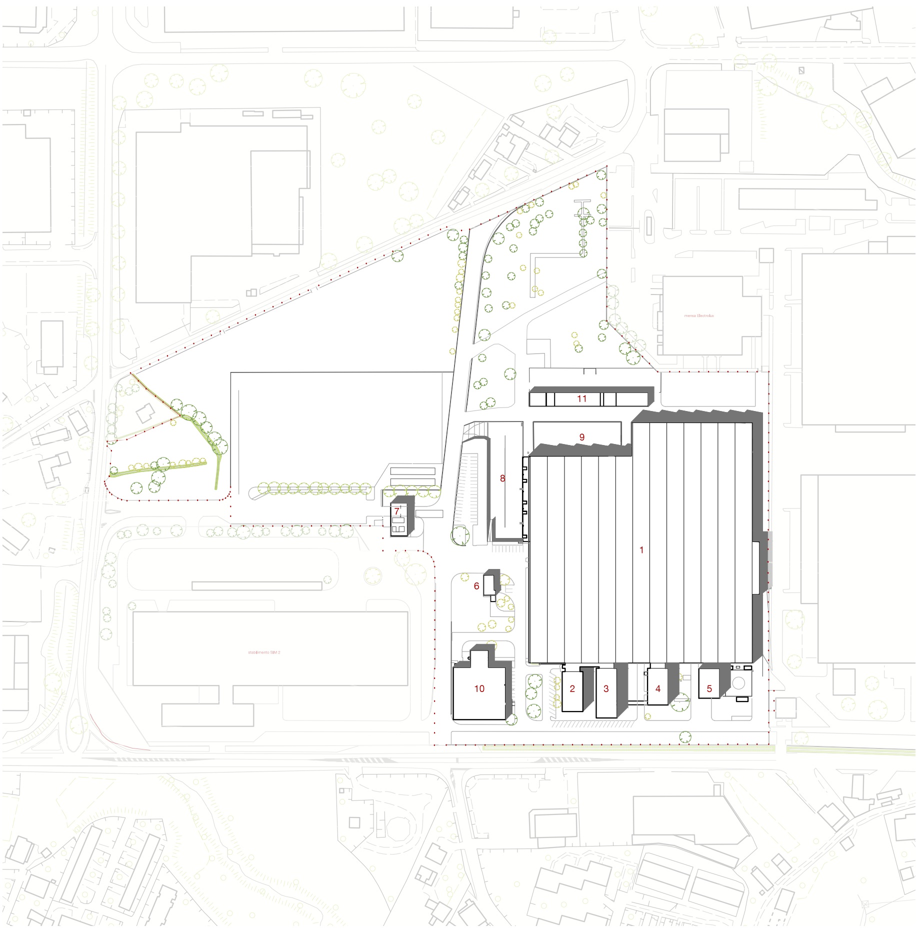
F. 3-17: South view of the Seleco building (2016)

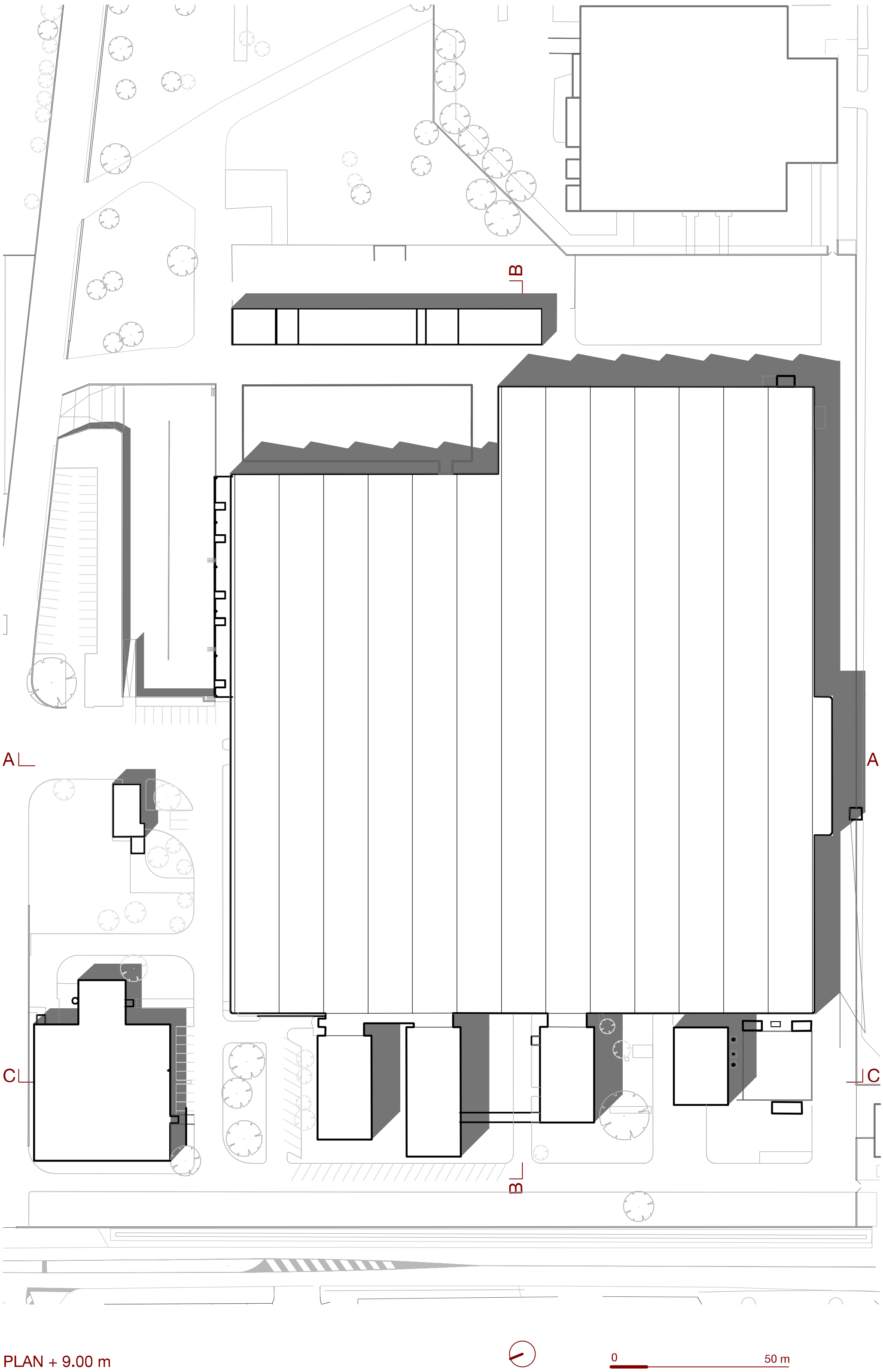
F. 3-18: interior view of the Seleco building (2016)

F. 3-19: interior view of the Seleco building (2016)

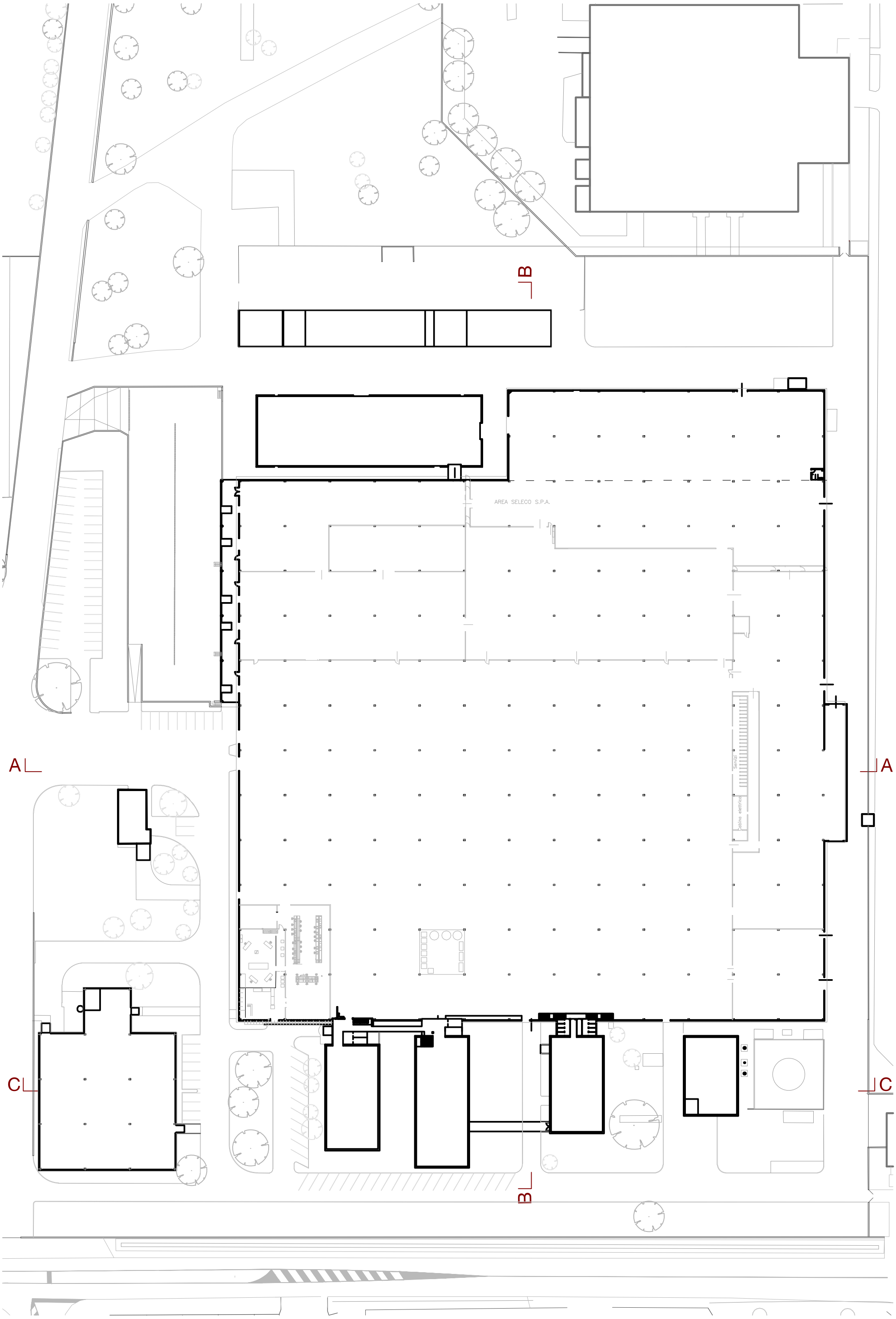
F. 3-20: interior view of the Seleco building, office block (2016)

	buildings in the site	area [m^2]	volume [m^3]
	outdoor area	125 000	
1	production area	26 750	214 000
2	office	960	3 840
3	office	1 040	4 160
4	changing room and canteen	760	3 040
5	heating plant	310	2 480
6	former reception	120	480
7	new reception	90	360
8	loading and unloading platform	-	-
9	inflatable dome	1 320	-
10	waste warehouse	880	2 640
11	accounting office	1 620	6 480
		33 850	



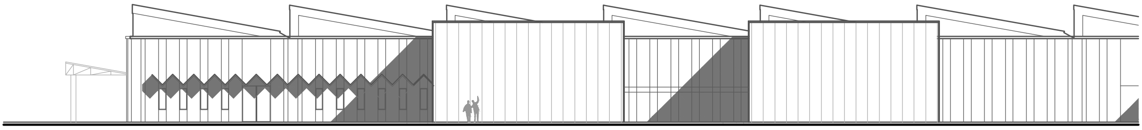


PLAN + 9.00 m

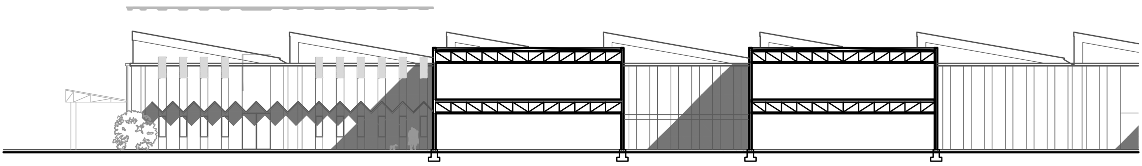


PLAN + 3.00 m

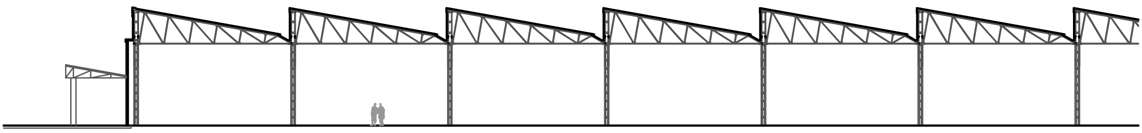
0 50m



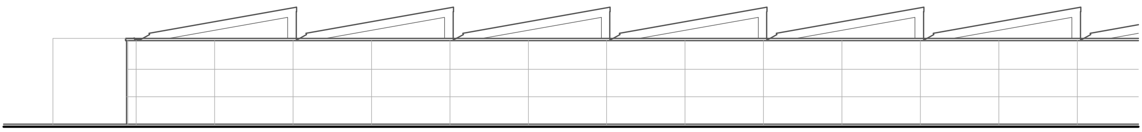
ELEVATION N-W



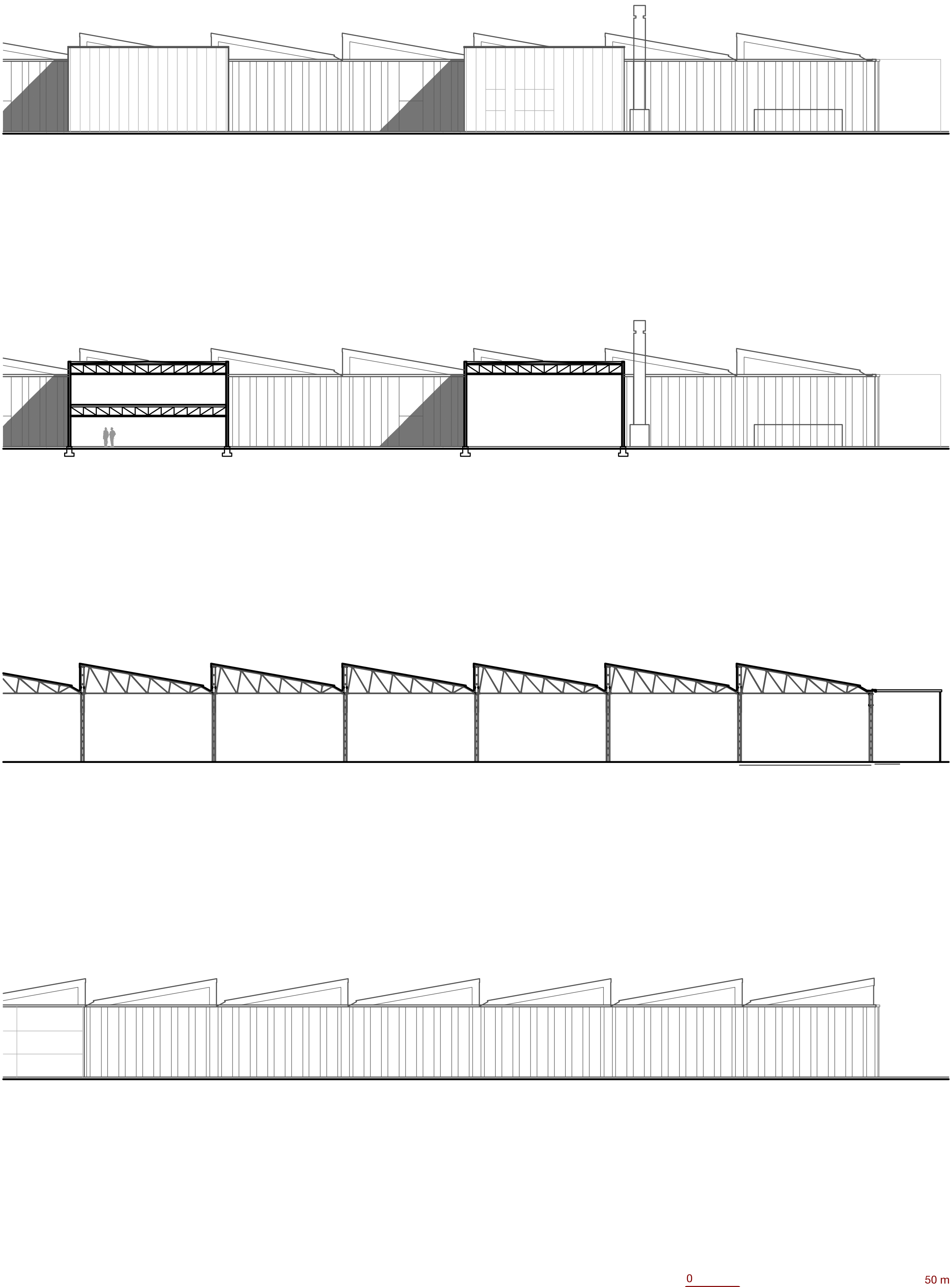
SECTION C-C

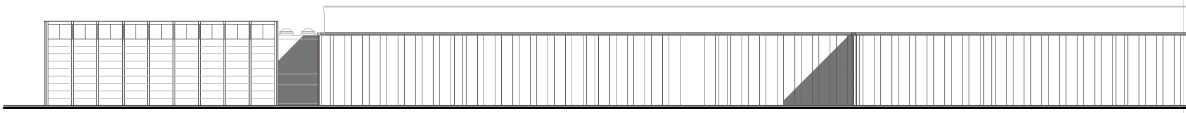


SECTION A-A

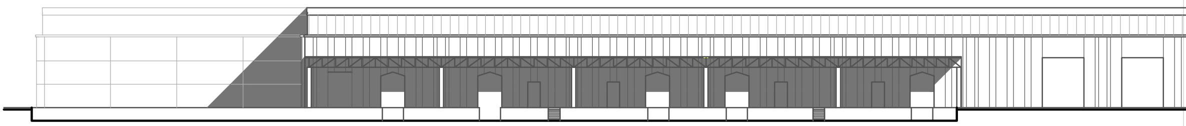


ELEVATION S-E


0
50 m



ELEVATION S-W



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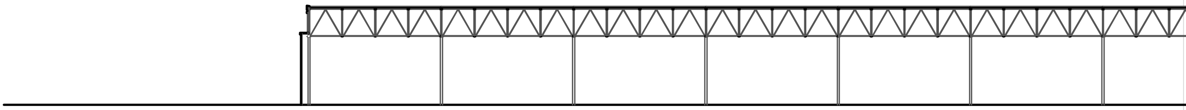
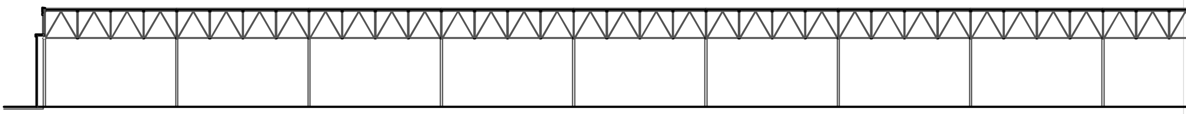
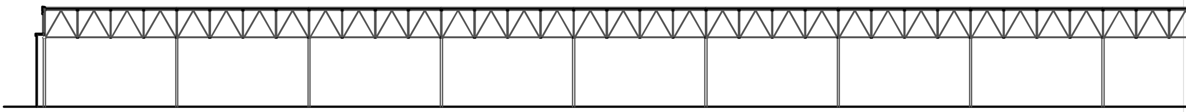


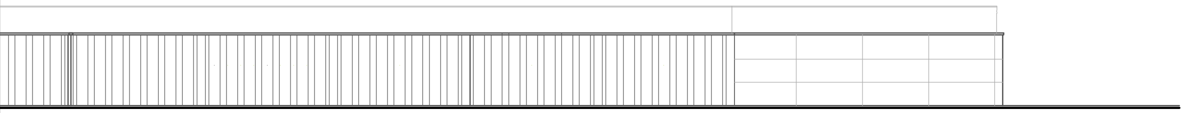
SECTION B'-B'

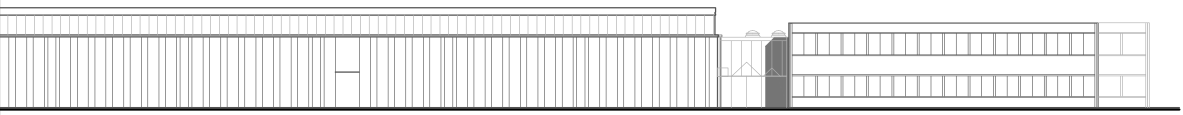


SECTION B-B

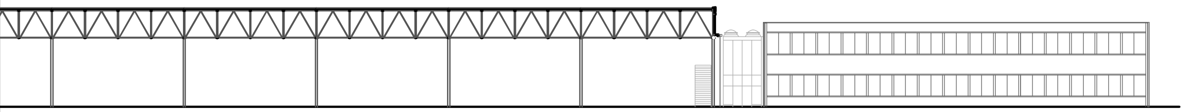


SECTION B''-B''

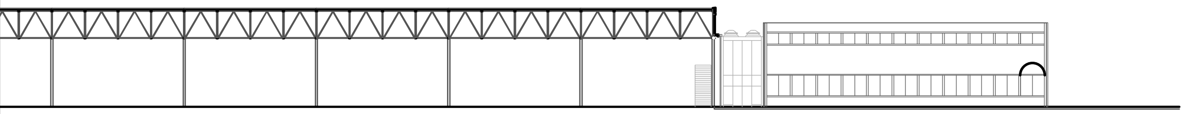




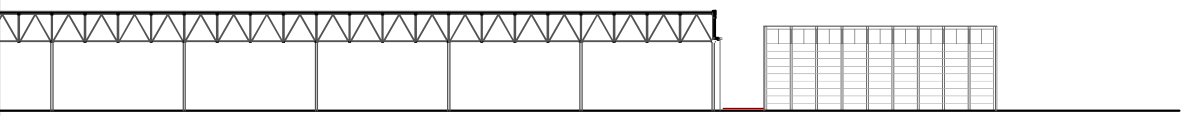
OFFICE



OFFICE

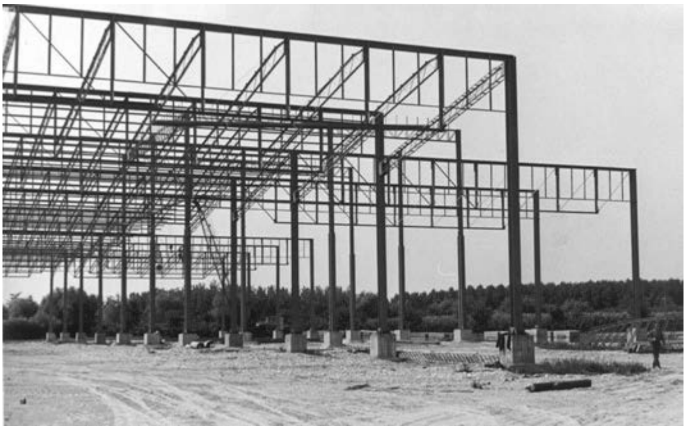


WORKS CANTEEN



HEATING PLANT

0 25 m



F. 3-21: construction of the Zanussi plant in Porcia, 1963, metal structure (Archivio Valle Architetti Associati)

F. 3-22: construction of the Zanussi plant in Porcia, 1963, interior view (Archivio Valle Architetti Associati)

F. 3-23: Zanussi plant in Porcia, 1964 (Archivio Valle Architetti Associati)

3.2.2 Constructional and technological features

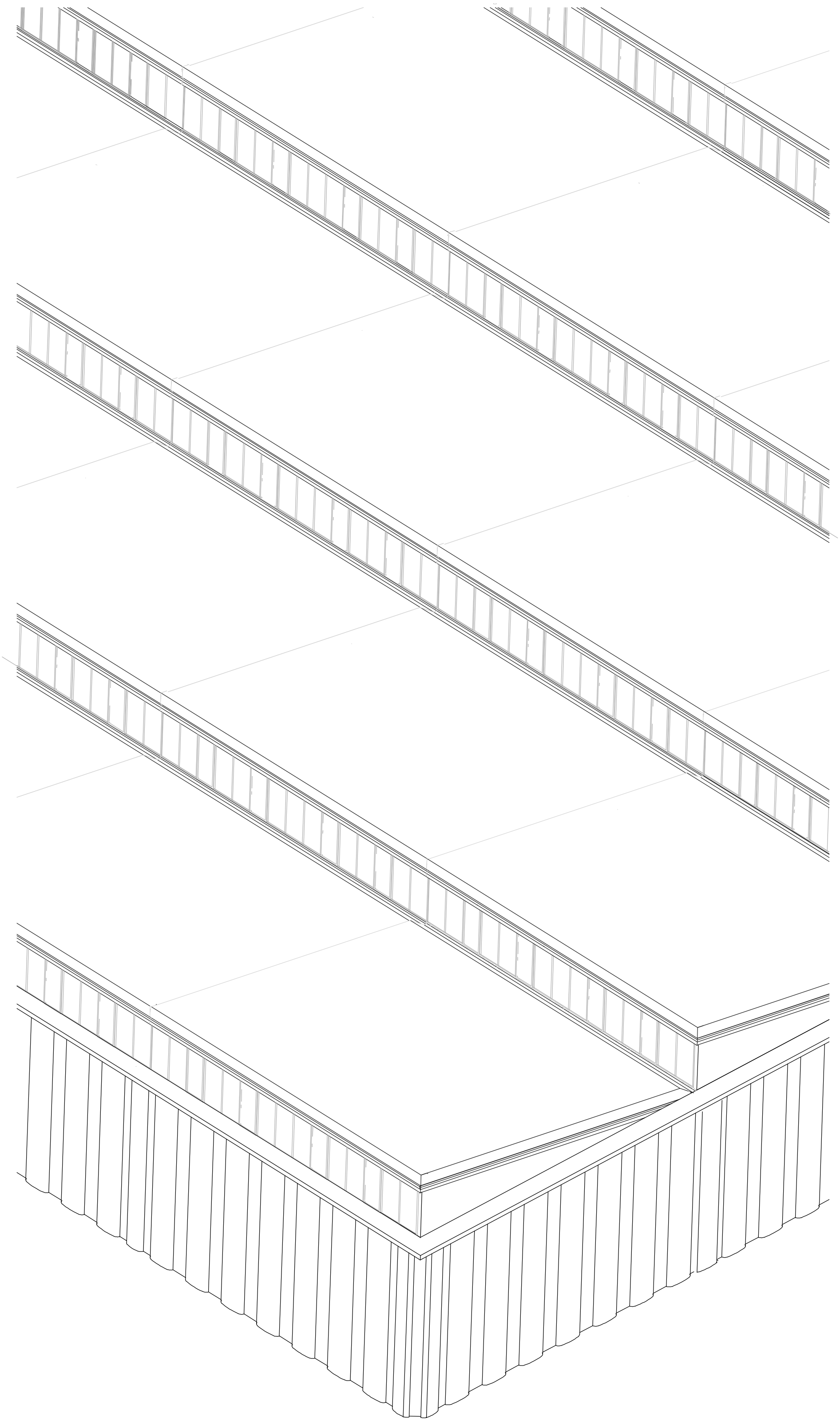
All the buildings that compose the site, despite the differences in types, are characterised by a metal bearing-structure combined with precast concrete cladding.

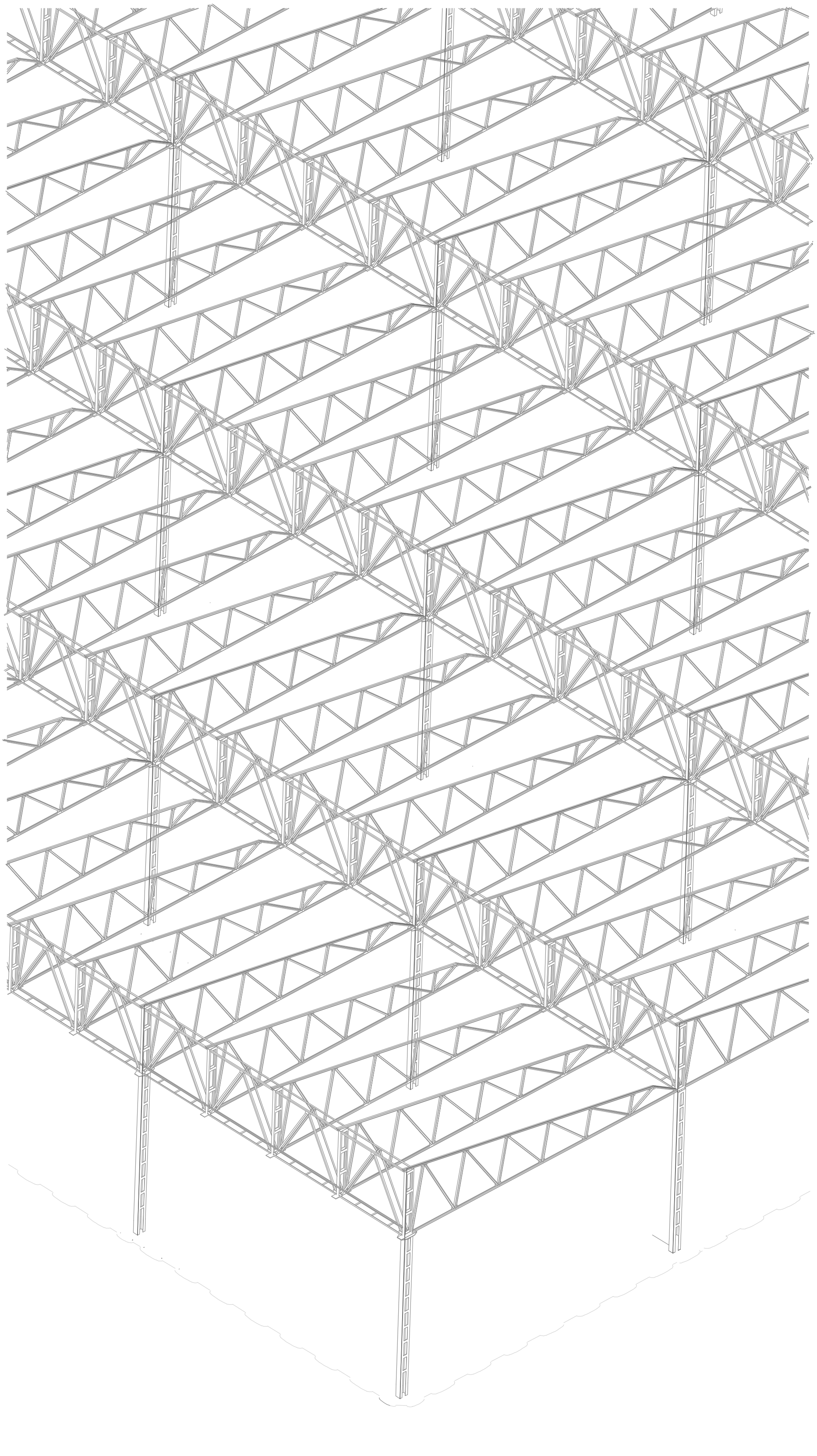
The office buildings are two-storey blocks, organised on a modular grid of 1.20 metres, constructed with a large number of perimetric metal pillars and trusses which form floors and flat roofs; the vertical structures consists of ribbon windows and precast concrete cladding panels, laying horizontally in the longitudinal façades and vertical in the façades along the street - a feature which is no more visible after the recladding; only the block for the thermal plant, which was formerly different from the others, still possesses the original materials and appearance.
The main building, for the production, is characterised by a shed roof, made of a metal structure and precast concrete cladding along the whole perimeter.
In structural terms, the building consists of a large number of pillars positioned in a grid pattern with a module of 12.50 x 12.50 metres. The columns are supported by concrete plinths. The roof comprises triangular metal trusses supported by steel profiles lined with corrugated metal sheet[154]. In detail, the rectangular pillars support the system of trusses consisting of L profiles of variable thickness and composed differently in the longitudinal and transverse direction to form the trusses or the gables.
The windows on the sheds are made with steel frames and wire reinforced glass, while all the openings along the perimeter of the building are metal industrial doors.
System and services includes fuel storage, electrical box, thermal plant. The heating system is organised in different areas: areas with radiators (changing rooms, toilets inside the main buildings), and areas with electric radiant heaters on the ceiling. The electrical system includes an industrial and a domestic ring. Only some parts of the buildings have electrical outlets and a water system.

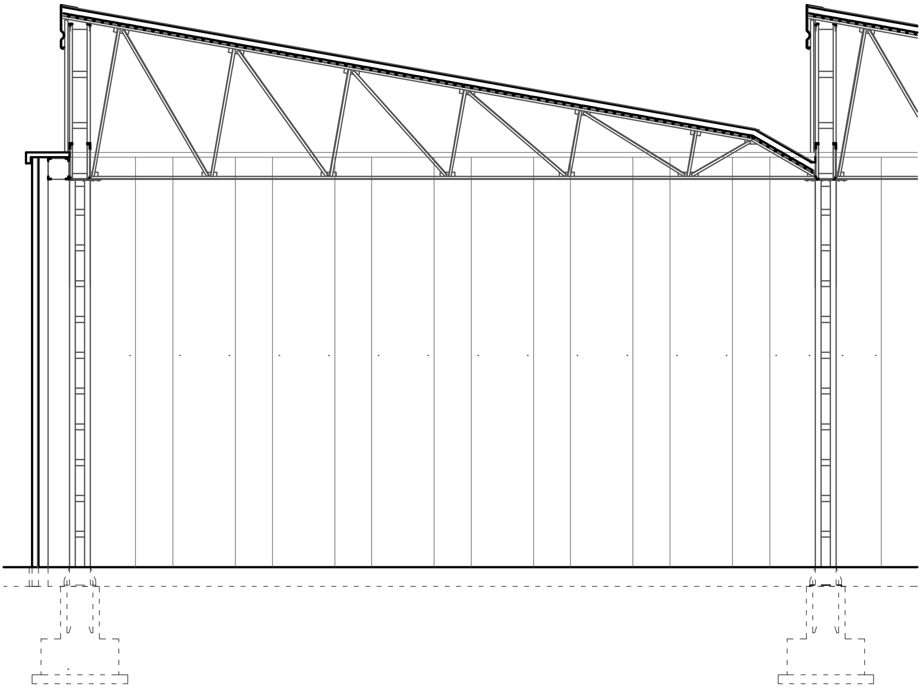
The actual construction of the complex was carried out by the company Zanussi itself, the Industrial Building Division of Zanussi Industries[155], which was located in the former REX factory in Via Montereale and later became *Zanussi Farsura* (Baccichet *et al.*, 2016). The prefabricated concrete panels appear to be, instead, produced in the SIPRE precast plant in Udine.

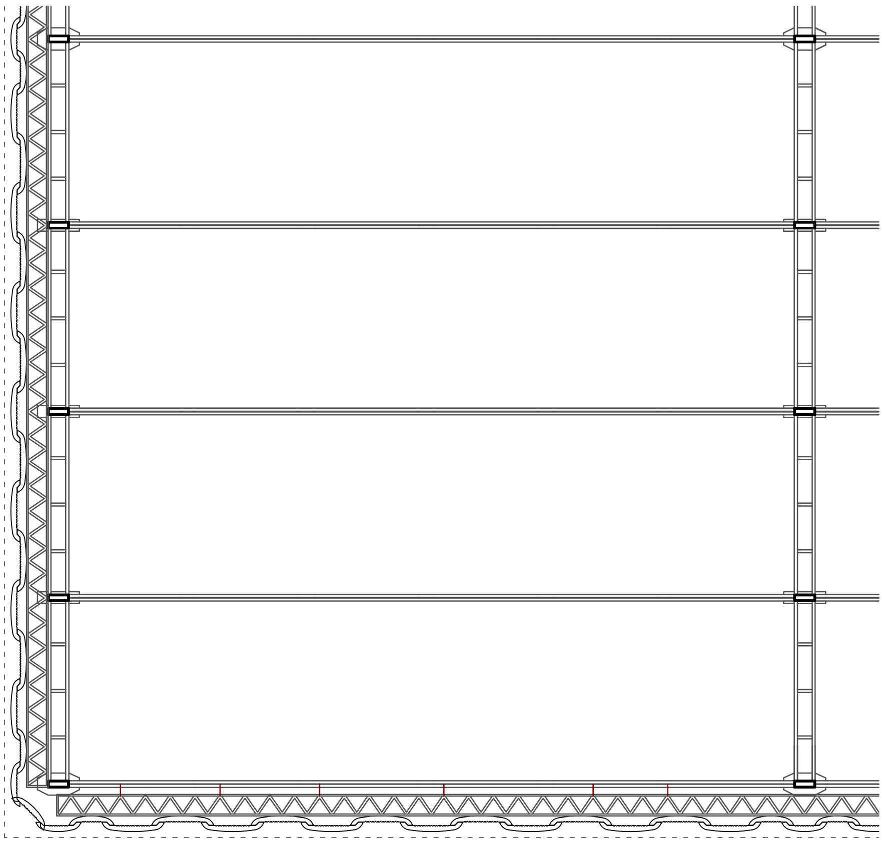
[154] In the documentation archived in the municipal offices, the roof is reported as being insulated asbestos cement; the owner and the company reported that the roof package consists of a cover in sheet aluminium, insulating layer of rock wool and a bearing layer of corrugated sheet steel.

[155] Even though this was not a unique case, as many other industries which operated in the region at that time also had divisions dedicated to building construction works the evolution of the Building division of the Zanussi industries, especially in the ZEI, is particularly interesting, as illustrated in chapter 1.

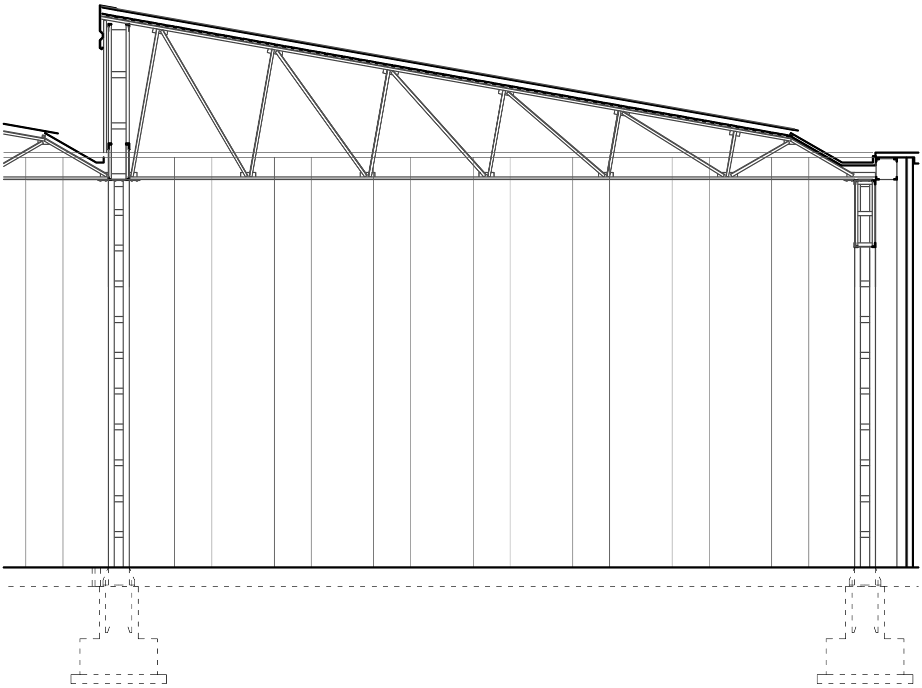


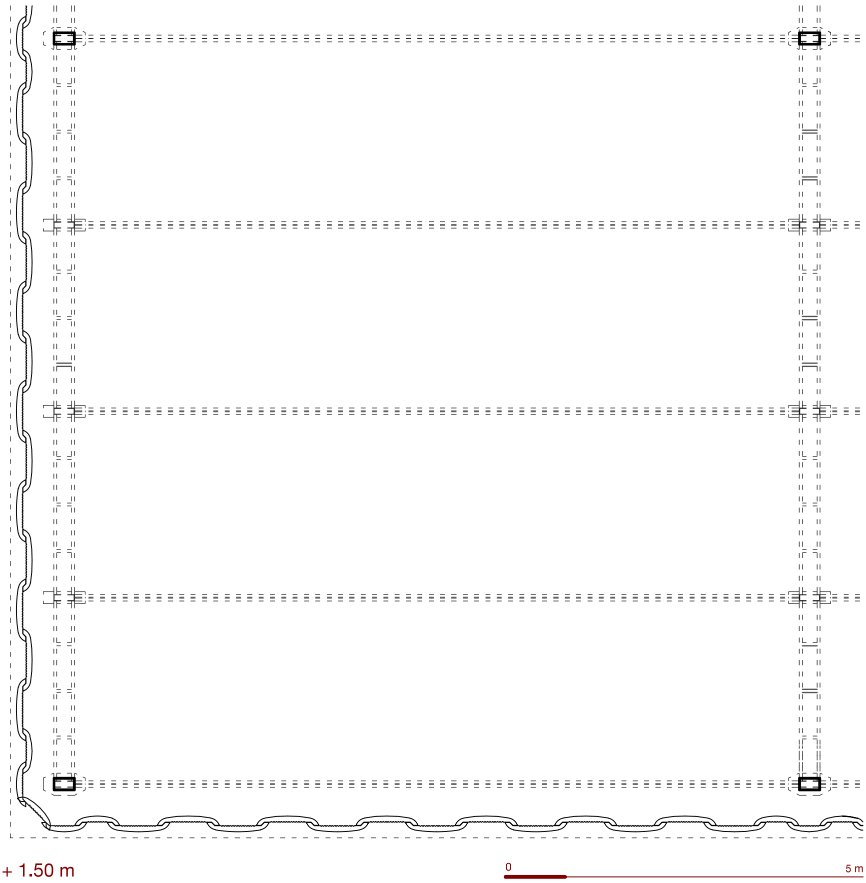




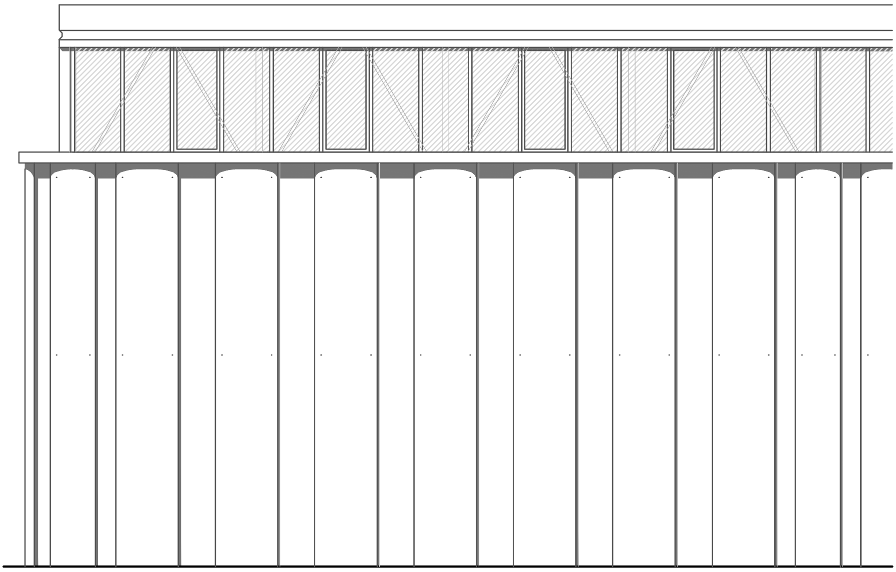


PLAN + 6.50 m

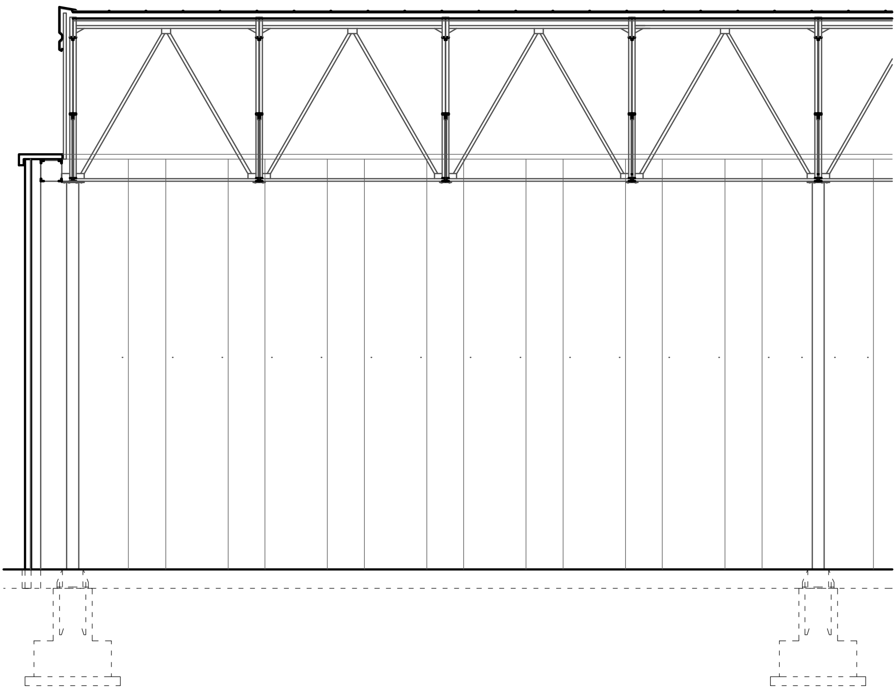




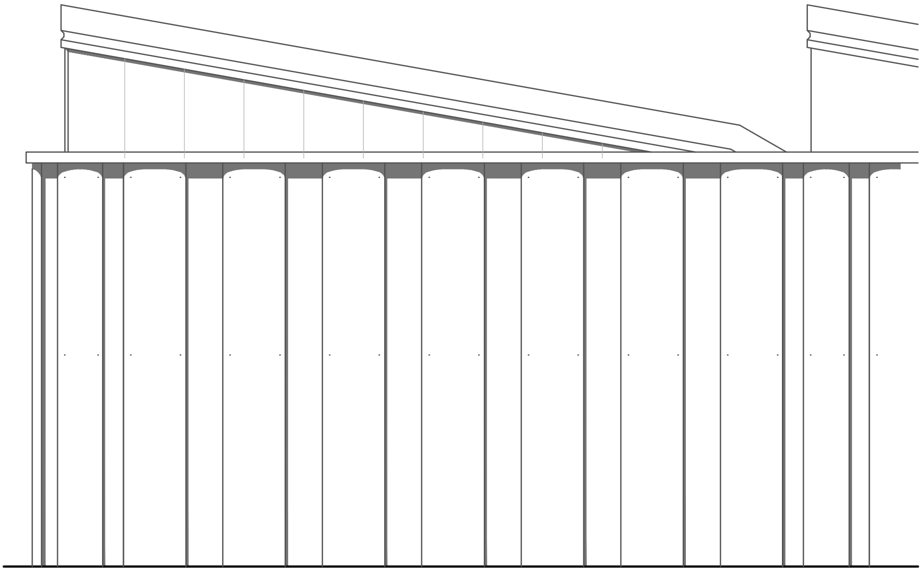
PLAN + 1.50 m



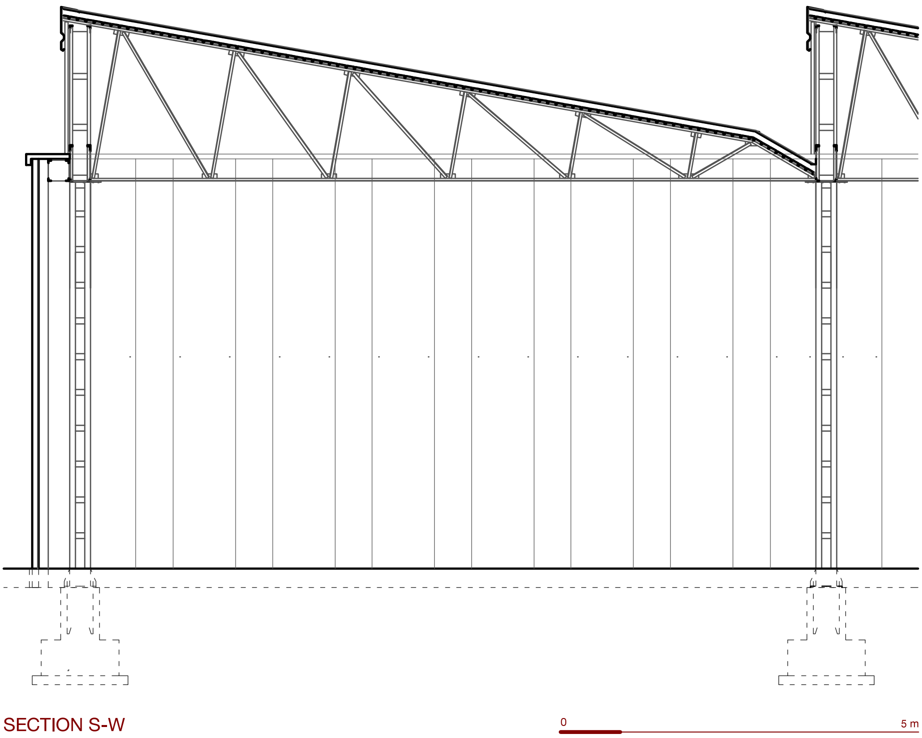
ELEVATION N-E



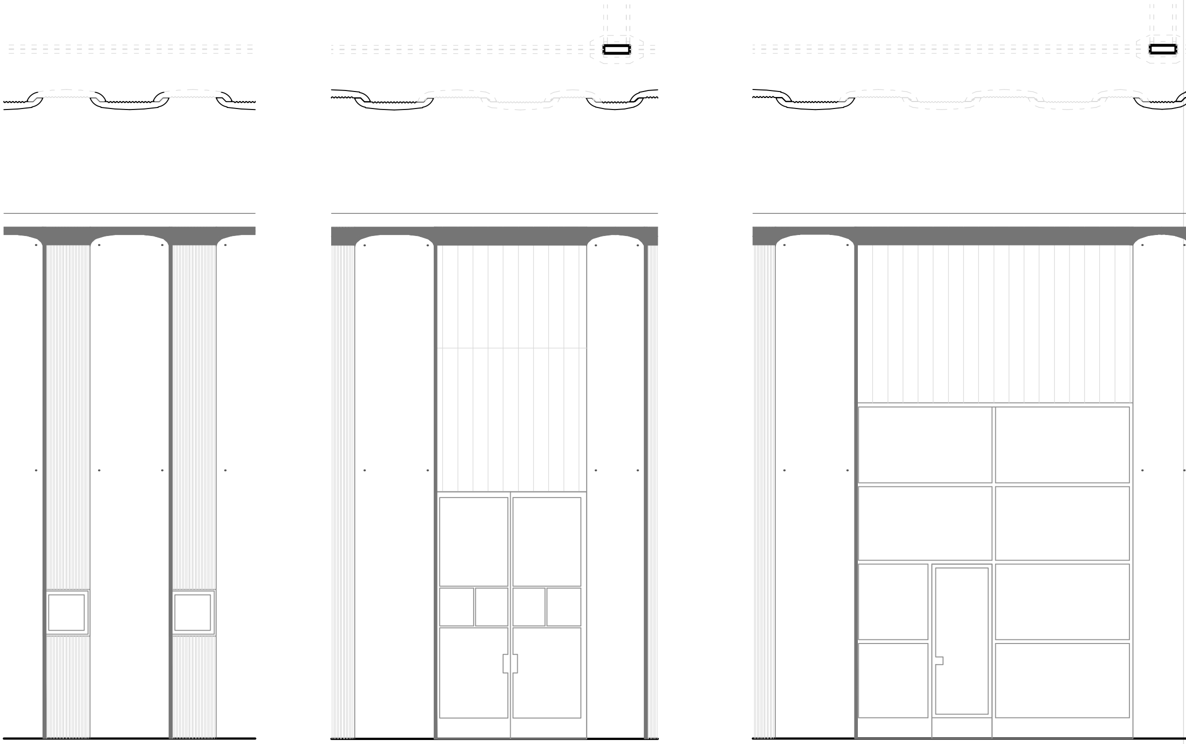
SECTION N-E



ELEVATION S-W



SECTION S-W



DOORS AND WINDOWS - ORIGINAL

DOORS AND WINDOWS - ADDITIONS


0
5 m

F. 3-24: façade of the Seleco building (author, 2016)

F. 3-25: : façade of the Seleco building (author, 2016)

3.2.3 The special precast concrete panels

The skin of the building, characterised by the original design of the façade and the cladding elements, is definitely the distinctive character of the Sèleco factory. The façade is made of precast reinforced concrete panels, shaped and assembled according to an original system designed by Valle and also used in the Zanussi factory in Porcia (1964) and in the adjacent *Zanussi Grandi Impianti* building (1968).
In that period, in fact, research carried out by Valle into industrial buildings (architecture reproducibility and prefabrication) focused precisely on the constructional definition of the cladding components and their assembly (Croset and Skansi, 2010): for the Sipre factory (1962-1963) he proposed a reinforced concrete panel assembled with a flexible joint which allows angles of 90, 45 or 135 degrees, while at the Scala ceramic factory he used flat panels joined with a transparent PVC element, and in the *Zanussi Cucine* plant he introduced for the first time a special tall narrow panel, known as the 'biscuit panel'. In this last case in particular the constructional choice appears for the first time combined with aesthetic considerations (Croset and Skansi, 2010). The reasons for the attention to the design of the façade lie also in the search for architectural quality for industrial structures which was recurrent in Valle's work: since the structural skeleton - often metal - could not have specific qualities, the aesthetic and architectural features had to be concentrated in the cladding panels (Croset, 2009).

The panel design dates back to 1963 and consists of a very tall and narrow precast reinforced concrete element which was not particularly thick and was of a peculiar curved shape, convex and with a smooth finish on the front side and concave and ribbed on the back side.
The first version of the panel was described as «a cladding system in prestressed reinforced concrete produced by Sipre. Each of these elements, 10 meters high and 90 cm wide, has a convex external side obtained through moulding and a flat ribbed internal surface obtained through mechanical finishing; (they) are assembled alternately - i.e. the external face of one panel is set next to the internal face of the subsequent panel - so that the elements are joined as a chain, connected to each other at the edges of the curve» (Gregotti, 1986). This solution, in fact, involves the assembly of the panels alternately front and back, creating a 'chained' façade and the theme of a colonnade which represents the structural rhythm of the building (Croset and Skansi, 2010). Thus the solution devised for the façade of the building Sèleco constitutes a particularly successful example of the way in which the design of the constructional detail can also control the large scale of the work (Croset, 2009).

A detailed analysis of the project and the building reveals that the panel actually exists in two versions: a narrow panel (75 cm) and a wider panel (105 cm). Furthermore, the element used in the factories of Vallenoncello can be considered a derived version of the first panel (used for the Zanussi plant in Porcia), due to some different features, such as a lower height than the original (7 m versus 10 m) or the assembly through a different number of anchors (2 instead of 4).

The forward and reverse assembly of the two types of panels made up the rhythm of the façade according to a modular principle based on the proportion 2:3. The sub-module of 27.75 cm is applied in the version 2/3M (55.5 cm) as the centre-to-centre distance between the narrow panels, while the M version (83.3 cm) as the centre-to-centre distance between the wider panels. This module allows the correspondence of 3 narrow elements with 2 wide elements in the space of 2M (166.6 cm). The modular composition thus allows coordination with the structural grid of 12.5 m, corresponding to 15 times M. Each span is therefore completed with 16 panels, of which 3 narrow ones (2 full and 2 half) and 13 wide ones; in particular, in the overall composition of the façade, the narrow panel (front) always coincide with the pillar - and is then followed by a narrow panel back, 7 wide panels front and 6 back, a narrow panel back, and finally a narrow panel front on the next pillar.

The concave-convex rhythm of the panels calls to mind the relationship between solid and voids in classical architecture, concept already proposed by Croset and highlighted by the ‘negative’ observation of the façade. These suggestions are supported also by the choice - quite unprecedented in the production of prefabricated elements of that time - of the ribbed finish for the internal face of the panel (with the presence of 13 or 17 vertical semi-circular grooves), almost an allusion to the fluted Ionic and Corinthian columns.
In this system the ring beam in concrete and the shed with the skylights might represent the entablature (architrave - frieze - pediment). Similarities with classical architecture are also reflected in the modular and proportional system used for the composition of the façade[156]:

On the other hand, the irregular rhythm of the panels (narrow and wide) along the entire façade, held together only by the crowning formed by the continuous concrete ring beam, suggest the idea of a textile skin. The panels make up a cladding that is not a flat and solid surface - a wall - but a curved and three-dimensional surface like a drapery or a curtain. The same correspondence between exterior and interior façade design (except for the presence of the face or back panels at the centre of the span), might confirm this interpretation.

---

[156]

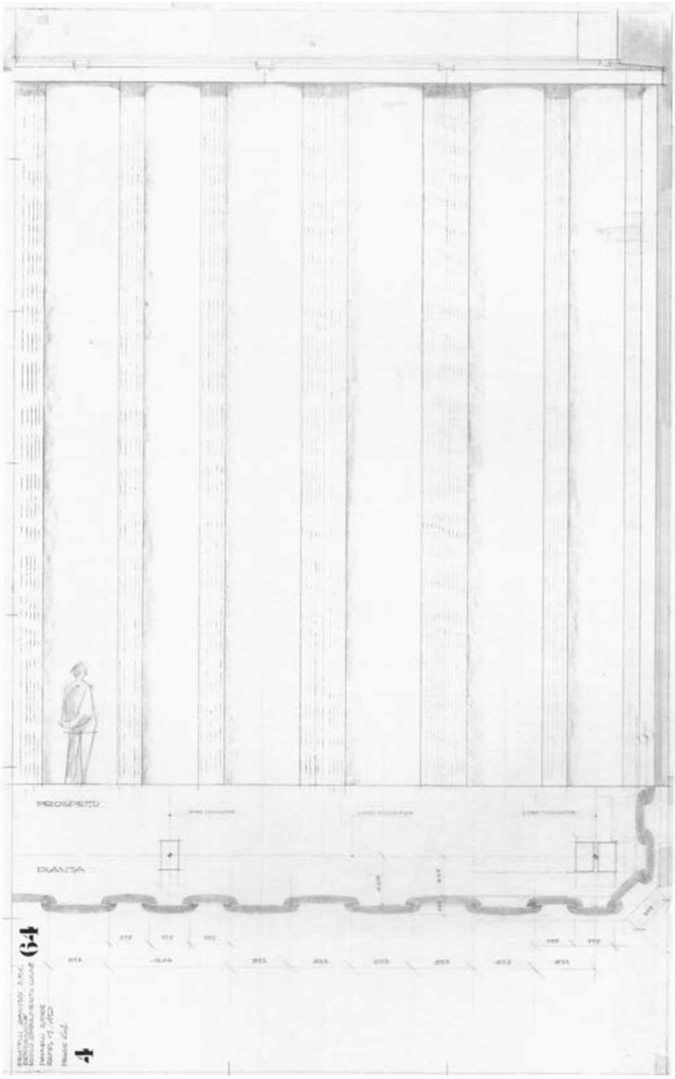
column diameter	1 D	panel back	62.5 cm
intercolumniation	1.5-3 D	panel front	105 cm
column height (H)	7-10 D = H	panel height	7.0 m
entablature	1/4 H	shed height	2.5 m - 2.25 m

Moreover, when discussing the work of Gino Valle[157], Zucchi mentions as an example the high biscuit-panels of the Zanussi plant. The panels, «chained together to form a great bar code, set up a short circuit between design and landscape, dodging with ease any reduction to the ordonnance of architecture (in his words, a 'non-architecture' that pursued a 'programmed invisibility')» (Zucchi, 2004).

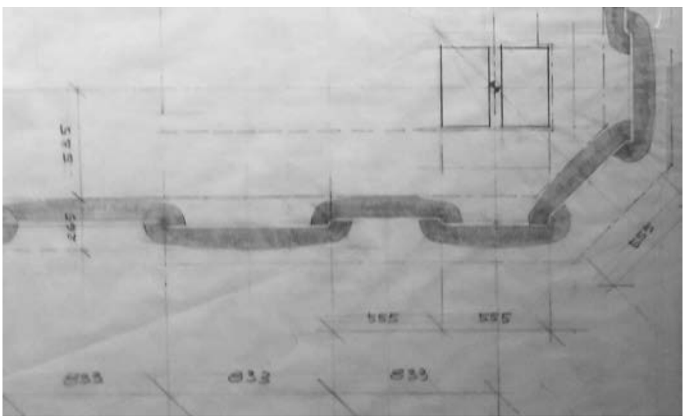
The idea of the bar code, appropriate even though it is anachronistic, subtends a correct reasoning referred to the relationship between architecture and the landscape, at a larger scale than that presently analysed, rather than to a proportional system used in the façade. However, it is a modular system of composition that in the design of the façade manages to connect and hold together the structure on the scale both of landscape and of architectural detail.

The arrangement of the panels with the exception to the rule at the pillars creates a pattern on a large-scale which underlines the structural grid (like the sheds) of the building; the alternation of front and reverse panels defines the narrow-wide pattern that creates the rhythm and the geometric composition of the façade (like the 7 columns); the shape and the surface treatment of panels determine the chiaroscuro and plasticity of the skin of the building, highlighting the architectural and design concept (base, panels, ring beam).

[157] «*Outside the city lay a territory whose rules we did not yet know, and Valle pointed a way in the style of a great carpenter, by ceaseless experimentation with the figurative strategies of the Venetian megalopolis*» (Zucchi, 2004).



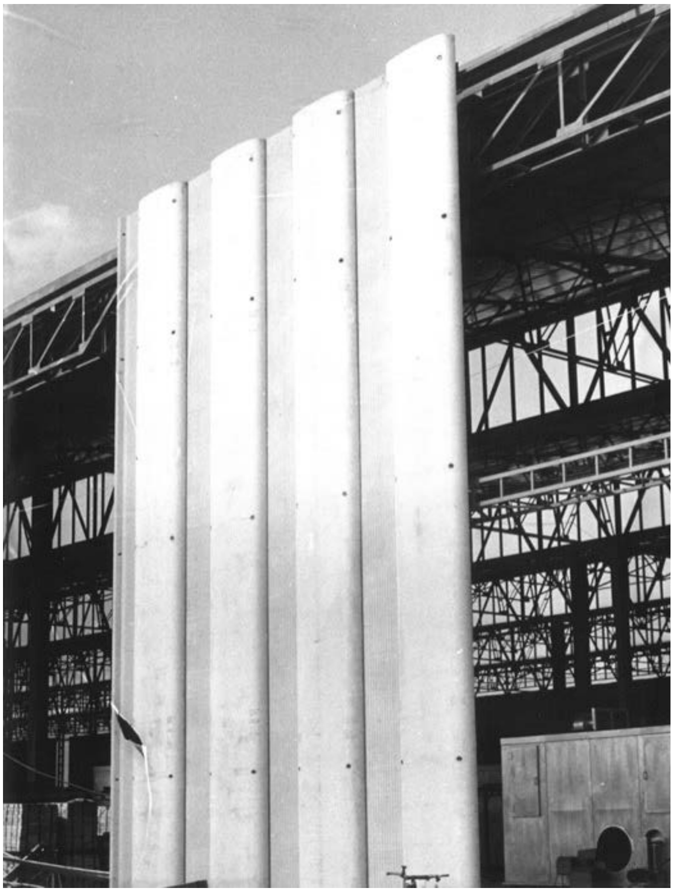
F. 3-26: design of the façade in precast concrete panels for the Zanussi plant in Porcia (Archivio Valle Architetti Associati)



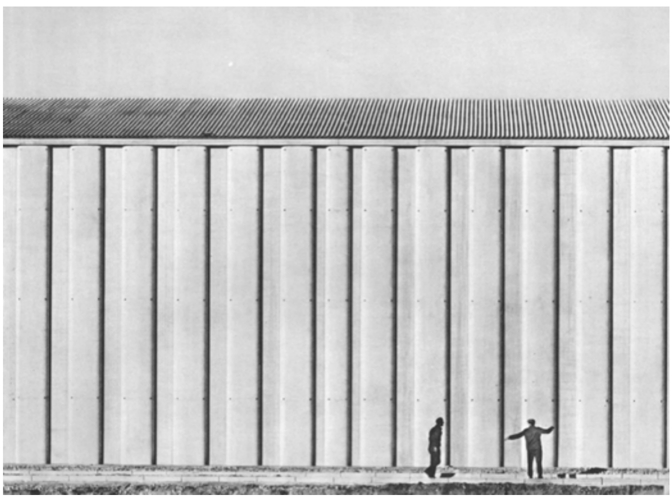
F. 3-27: detail of the façade in precast concrete panels (Archivio Valle Architetti Associati)

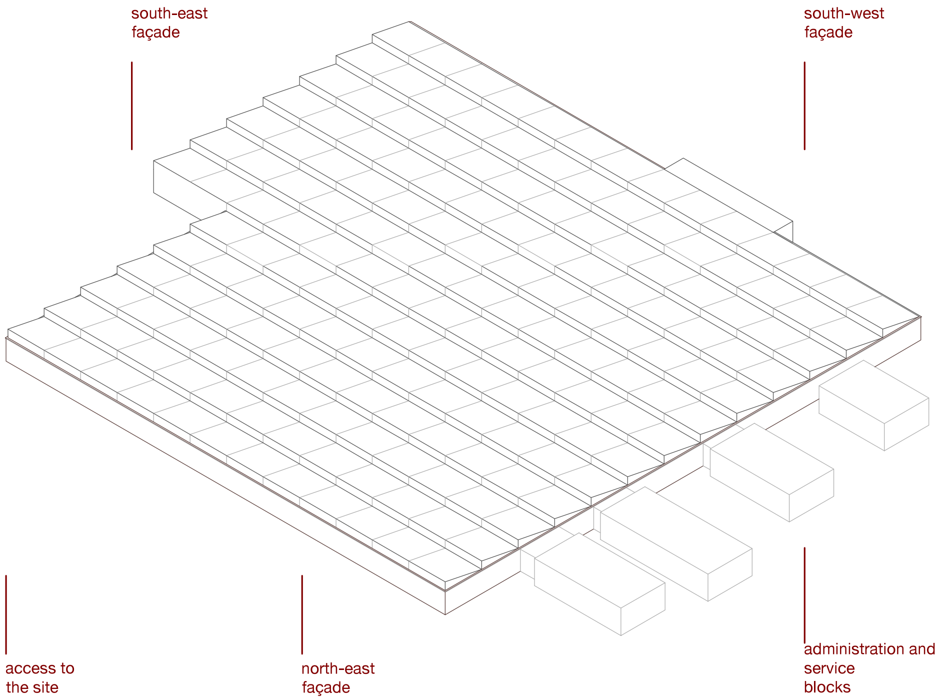
F. 3-28: construction of the Zanussi plant in Porcia, 1963, assembly of the panels (Archivio Valle Architetti Associati)

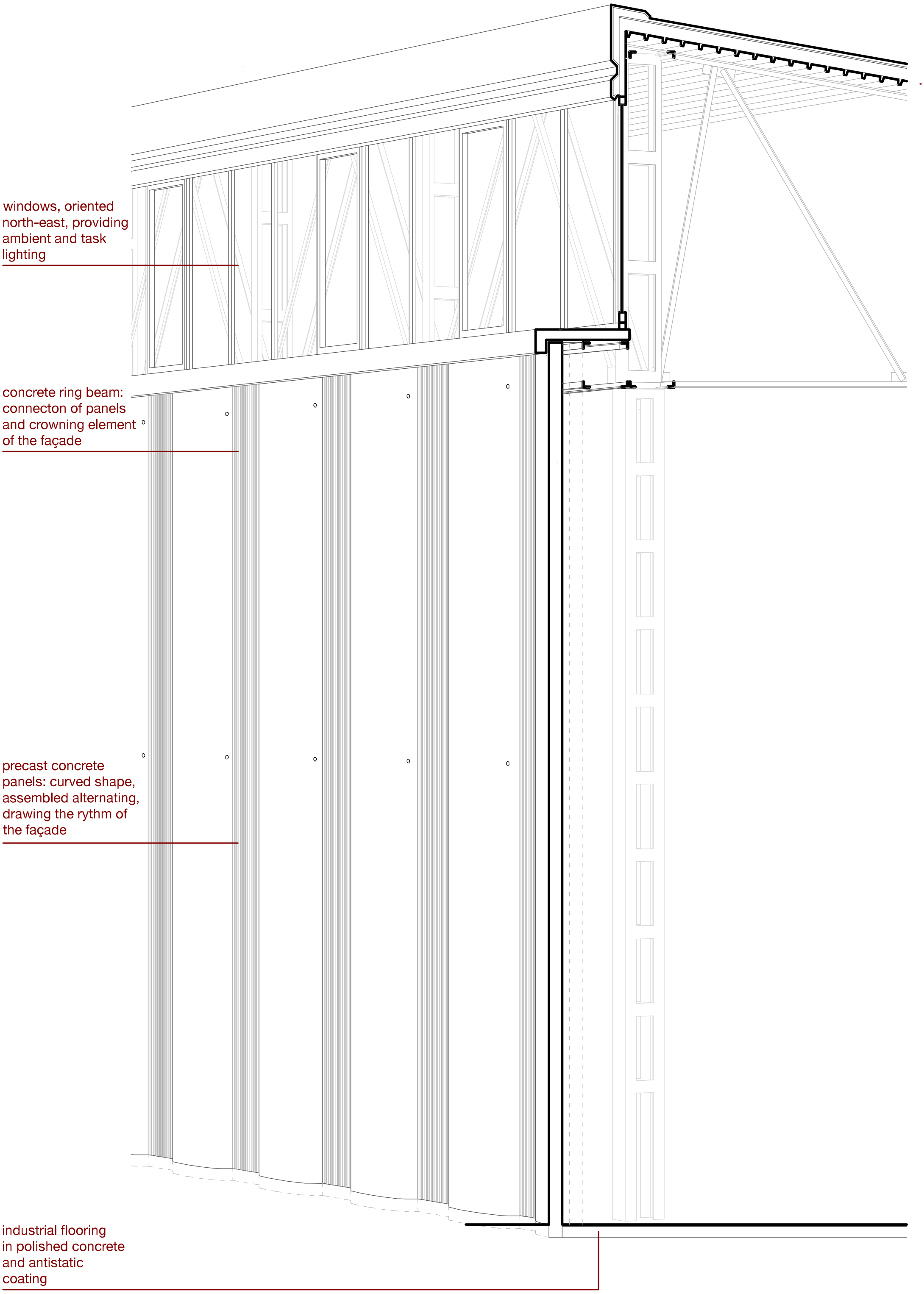
- in this building the panel is in its first version, more tall and assembled with four anchors.

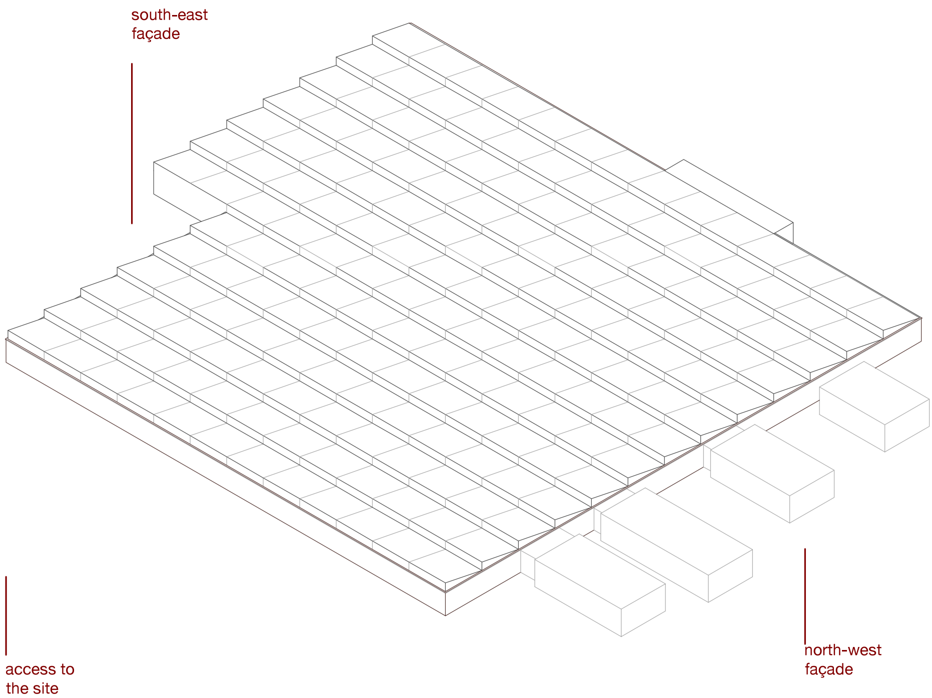


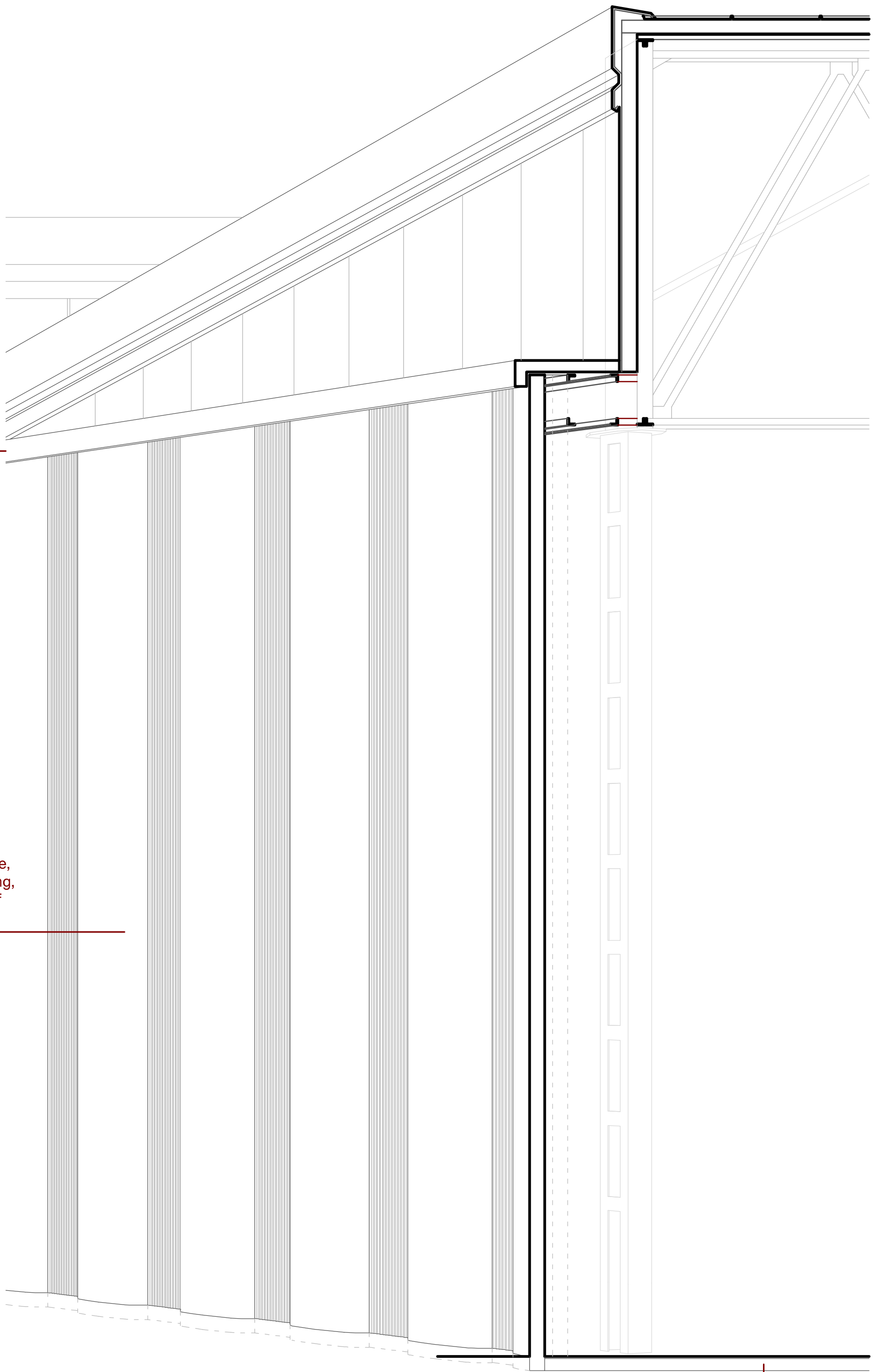
F. 3-29: Zanussi plant in Porcia, 1963, assembly of the panels (Corsini, 1972)




south-east
façade
south-west
façade
access to
the site
north-east
façade
administration and
service
blocks


windows, oriented north-east, providing ambient and task lighting
concrete ring beam: connecton of panels and crowning element of the façade
precast concrete panels: curved shape, assembled alternating, drawing the rythm of the façade
industrial flooring in polished concrete and antistatic coating

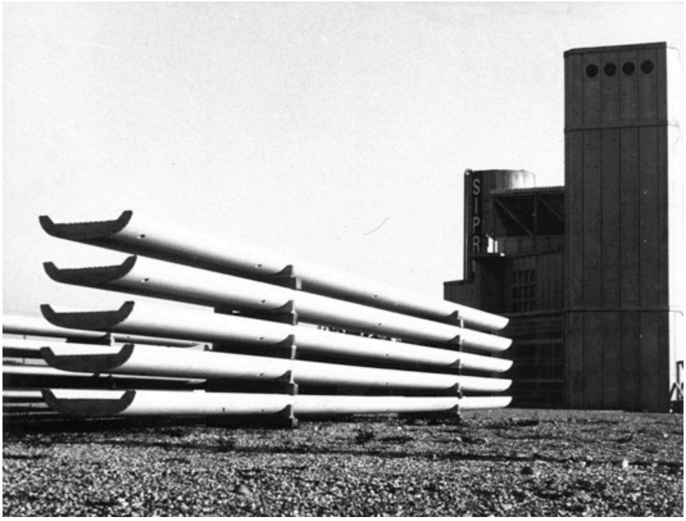

south-east
façade
access to
the site
north-west
façade



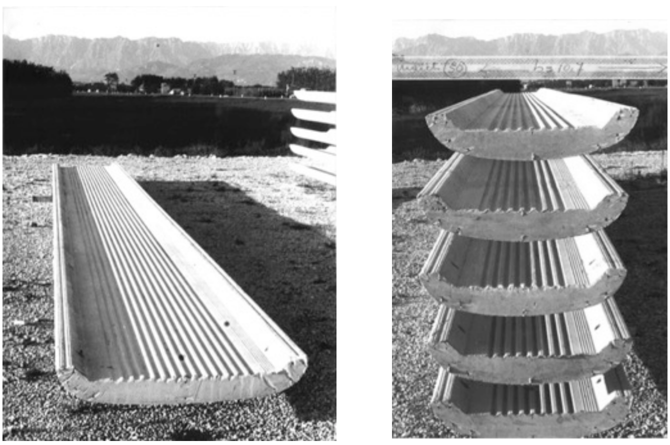
concrete ring beam:
connecton of panels
and crowning
element of the
façade

precast concrete
panels: curved shape,
assembled alternating,
drawing the rythm of
the façade

industrial flooring
in polished concrete
and antistatic
coating



F. 3-30: precast concrete panels outside the SIPRE precast plant in Tavagnacco, UD (Archivio Valle Architetti Associati)



F. 3-31: precast concrete panels, narrow and wide versions, outside the SIPRE precast plant in Tavagnacco, UD (Archivio Valle Architetti Associati)

3.3 Refurbishment and transformation

3.3.1 Urban and territorial context, regulatory framework, protection and new uses

The Zanussi Elettronica building (Sèleco) was an integral part of the company's policy of expansion, which involved the construction of plants in various areas of the Region, as previously explained. For the city, however, the most important aspect of the overall project was the actual location of the complex, which was intended to bring the factory closer to the workers, since most of the company's workforce lived in the residential areas to the south of Pordenone, and the aim of creating a new image of industrial Pordenone, which at the time was vying to become the capital of a new Province (Baccichet *et al.*, 2016). The building was therefore located along the Pordenone-Oderzo main road - which at the time was being constructed by a consortium comprising the Municipalities of Pordenone, Prata, Pasiano and Oderzo.
The building is still well connected with servicse and infrastructures, being only few kilometres away from the A4 and A28 highways. The area has maintained its classification as an industrial zone in the south-west area of the city, as provided by the planning instruments.

Regulatory framework, feasibility and protection

For a long time, the regulatory framework regarding the area of the city of Pordenone had consisted of the Town Plan adopted in 1983[158], in compliance with the Regional Urban Plan (PURG); a new Town Plan was drafted in 2015 [159] and, after its publication, comments of the stakeholders were collected[160]. The company owner of the Sèleco building (Real Asco) submitted comments to the documents *Norme*

[158] The Plan was approved with the DPGR n.0191/Pres of 28/05/1986.

[159] The new Plan was adopted on 7th July with the City Council resolution no.26/2015; from then on the protective measures provided for by the regional legislation entered into force so that the City has suspended all the decisions until the date of entry into force of the new plan. Additionally, on the 14th of July the municipality submitted the Plan to the Friuli Venezia Giulia Region for the examination of compliance with higher-level planning instruments and sector policies. The Region stated the outcomes of the examination on the 27th of October 2015 (n. 035/2015).

[160] Simultaneously with the resolution of adoption, on the 5th of August 2015 (BUR 31), the plan documents were published in order to allow the persons concerned to submit comments on the Plan until the 18th of September of 2015.

Tecniche di Attuazione (NTA) and to the document *Zonizzazione* - Zoning. In detail, to the Article 36 for Zone D3, paragraph 2*, Destinazioni d'uso* (Intended uses), the owner asked for an extension of the possible uses for the building in order to include mixed functions that would allow the reuse and renovation of the property; additionally, for the Article 117, *Contemporary Architecture*, the owner asked for the building to be removed from the layer of morphologic-typological protection on the general plan. The Sèleco building was included in the catalogue of contemporary assets as an important example of industrial architecture of the city, basically due to its author being Gino Valle. On the other hand, as the owner also pointed out, the building is similar in type, morphology and materials to other buildings in the area that have not been listed (i.e. the adjacent *Zanussi Grandi Impianti* building).

The new Town Plan of Pordenone was finally adopted in 2016[161], and the Sèleco building is still labelled as *Contemporary Architecture* (Document CO 01_13_Zoning).

The provisions for the category[162] explain how, in the zoning drawings, buildings of contemporary architecture which are important examples of contemporary building production due to their morpho-typological or formal features, are identified with a specific symbol. The transformation of these buildings is subject to the submission of a special report which should outline: the morpho-typological characteristics of the structure and its formal and spatial relationships with the urban surroundings; the redevelopment criteria and the results expected in terms of building redevelopment and overall improvement of urban quality, the demolition of these buildings being permitted only in the case of justified and documented reasons.

The Sèleco building is included in the D3 Zone - Existing industrial settlements[163]; the technical regulation of the Town Plan provide for specific requirements for this zone and, in particular, about intended uses it specifies that the permitted functions for these areas are:

- industrial (at least 51%);
- wholesale commercial;
- business under the Regional Law 19/09 (art. 5, paragraph 1, point e): leisure, health and education functions are permitted only if associated with industrial activities;
- services related to industrial activities;
- residential (maximum 100 m^2 area for each building);
- public services;
- commercial, only if already existing (and authorised before 1999);

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[161] The new Plan was adopted with the resolution of the City Council on the 22nd of March 2016 (n. 15/2016); the Plan was then published and entered into force from the 27th of July 2016 (BUR 30 - Decreto n° 0143/Pres del 12 luglio 2016).

[162] The provisions for intervention are included in TITLE VI - CHAPTER I - RULES OF INTERVENTION - Art. 117 of the Town Plan (www.comune.pordenone.it/it/servizi-online/prgc-online/elaborati-prgc-approvato/componente-operativa).

[163] Art. 36 - Zona D3 - Zona degli insediamenti industriali e artigianali esistenti, Norme Tecniche di Attuazione, Piano Regolatore Generale Comunale di Pordenone, 2016.

- other uses are however permitted if in force before the date of adoption of the Plan.

The possibilities for transformation of the property in compliance with the regulation are therefore fairly limited.

The first possible approach is the renovation of the building, maintaining the productive function as the predominant one, with a request for derogation of the planning instruments regarding uses which exceed those outlined by the Regional Plan - limited to uses already existing at the date of adoption of plan.

The second solution implies the request for a variant to the Regulation Plan, which is possible after an agreement between private and public administration and/or through a programme sponsored by the Town Council and the Region, aimed at creating a multifunctional building for private use, but providing for the construction and free distribution of works and facilities of municipal public interest. The process might be interpreted as a part of an overall urban regeneration programme, in which the focus on the renovation of a private property is balanced by works dedicated to public use.

Additionally, the plan envisaged the possibility of temporary uses for the building[164]. Aimed at encouraging the use of disused spaces and buildings in zones D, the regulation permitted temporary uses in order to facilitate the development of economic activities and promote the reuse of abandoned or underused facilities. The maximum duration of the activities is 24 months from the authorization to proceed (the authorization is temporary and not renewable and the duration of the activity must be specified in the request). As regards D zones, other uses are allowed in addition to those mentioned in the Town Plan: administrative or professional activities, such as offices, agencies, associations, unions and parties; spaces for recreational activities such as dancing, discos, film and theatre; other building works with minimal planning restrictions are allowed.

Reuse perspectives: new manufacturing and temporary uses

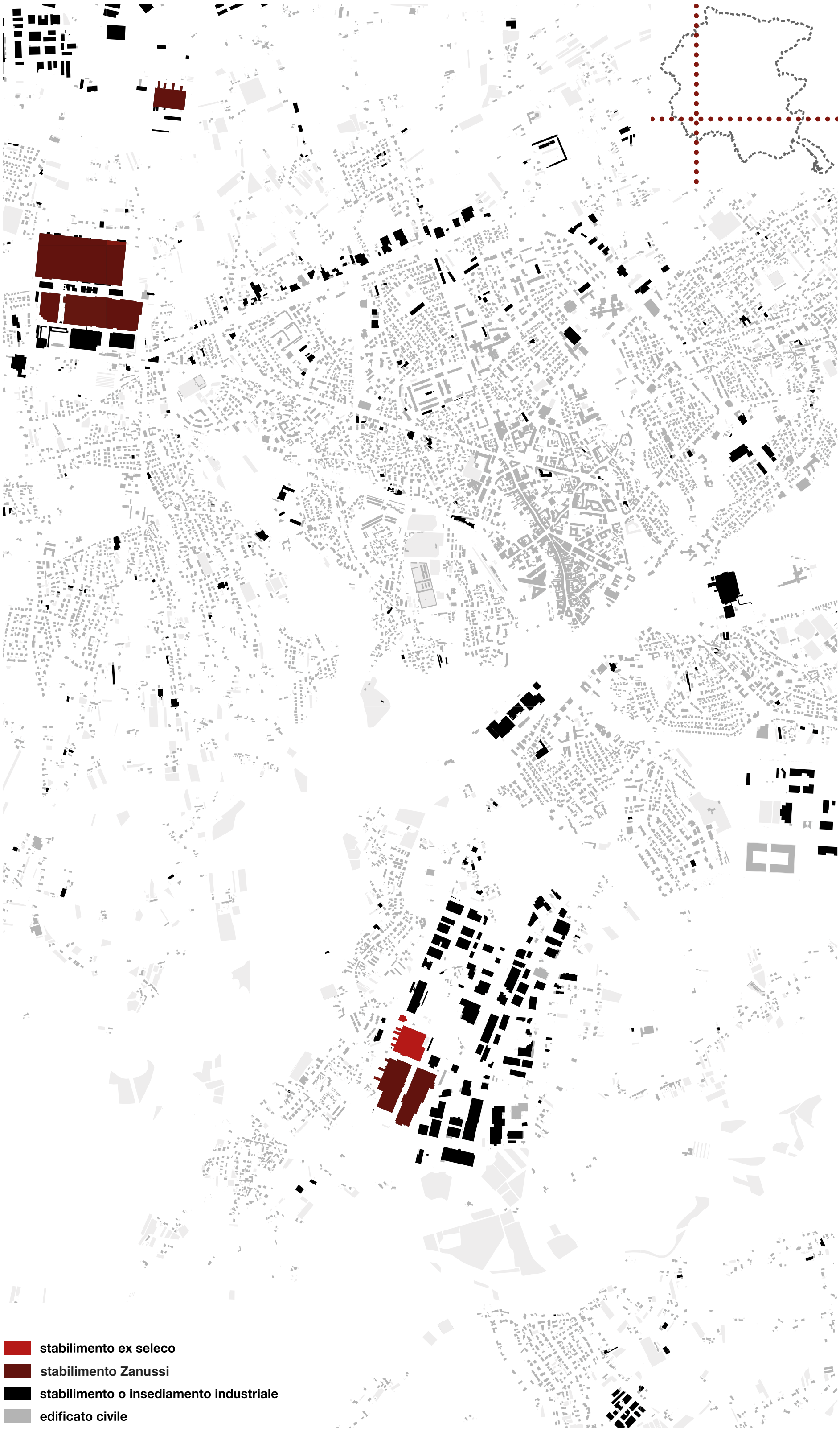
In this context of the crisis of the industrial sector in addition to the many restrictions on possible new uses, the objective of this study is not to propose a new function for the site, but to identify a series of valid strategies and actions which might contribute to the redevelopment of the building, making it suitable for a multiplicity of possible re-uses. The aim takes into account current approaches to the reuse of industrial spaces (chapter 2.2) with a particular focus on new forms of work and the temporary

[164] Art. 13 - Usi Temporanei - Norme Tecniche di Attuazione, Piano Regolatore Generale Comunale di Pordenone, 2016.

activities. Among the future possible uses, in a list that does not claim to be exhaustive, various interesting and innovative activities have emerged[165].
One possible strategy might be the conversion of the site for cultural uses, such as the idea of a 'district of knowledge'. This solution, following some succesful past trends in approaches to transformation of industrial heritage, pursues the conversion of the area from production centre to service centre for the city, as a place to retain and promote knowledge within the Italian territory, in a time when there has been a worrying migration of intellectual abilities and concurrently a major low-skilled labour immigration flow. Another solution might involve the creation of spaces/centres for cultural and leisure activities, which range from sport and wellness to performing arts, music, cinema.

The new working activities related to the innovative technologies and alternative way of working have emerged as particularly appropriate functions for the former industrial spaces.
On the one hand, even in Italy, the widespread diffusion of FAB-LAB illustrates this attitude clearly. Fabrication laboratories - often accommodated in former industrial buildings - are small-scale workshops which offer customised services for digital production, and usually include flexible manufacturing equipment: from rapid prototype such as 3D printers, CNC machines and cutters to digital electronics design, assembly, and test stations.
Furthermore, the growing interest in recycling of materials has recently favoured the stemming of initiatives and spaces for the design and fabrication of recycled goods - which however retain their link with the original products or the local industry, such as the wood and furniture sector or the electronics sector in the area of Pordenone.
On the other hand, former industrial space of this type can easily accommodate new business activities in the forms of start-up incubators, enterprise condos, and temporary offices.
The extensive topic of temporary uses has also emerged in recent years and might be a highly appropriate strategy for reusing the large spaces of industrial buildings. Temporary settings allow the experimentation of innovative interior design solution as well as the exploration of new uses related to current socio-economic needs, such as the issue of refugee dwellings.
All the above-mentioned approaches and new uses could however coexist in a renovation and reuse project which attempts to interpret the multiple and ever-changing needs of out times, providing a functional mix suited to the local dynamics.

[165] The Sèleco building was proposed as a case-study for the design workshop Laboratorio di Progettazione Architettonica I (4th year) of the Master Degree course in Architecture at University of Udine, A.A. 2014/2015, professors Giovanni La Varra and Simonetta Daffarra. The students came up with interesting proposals for the future use of the building, including some of those above-mentioned.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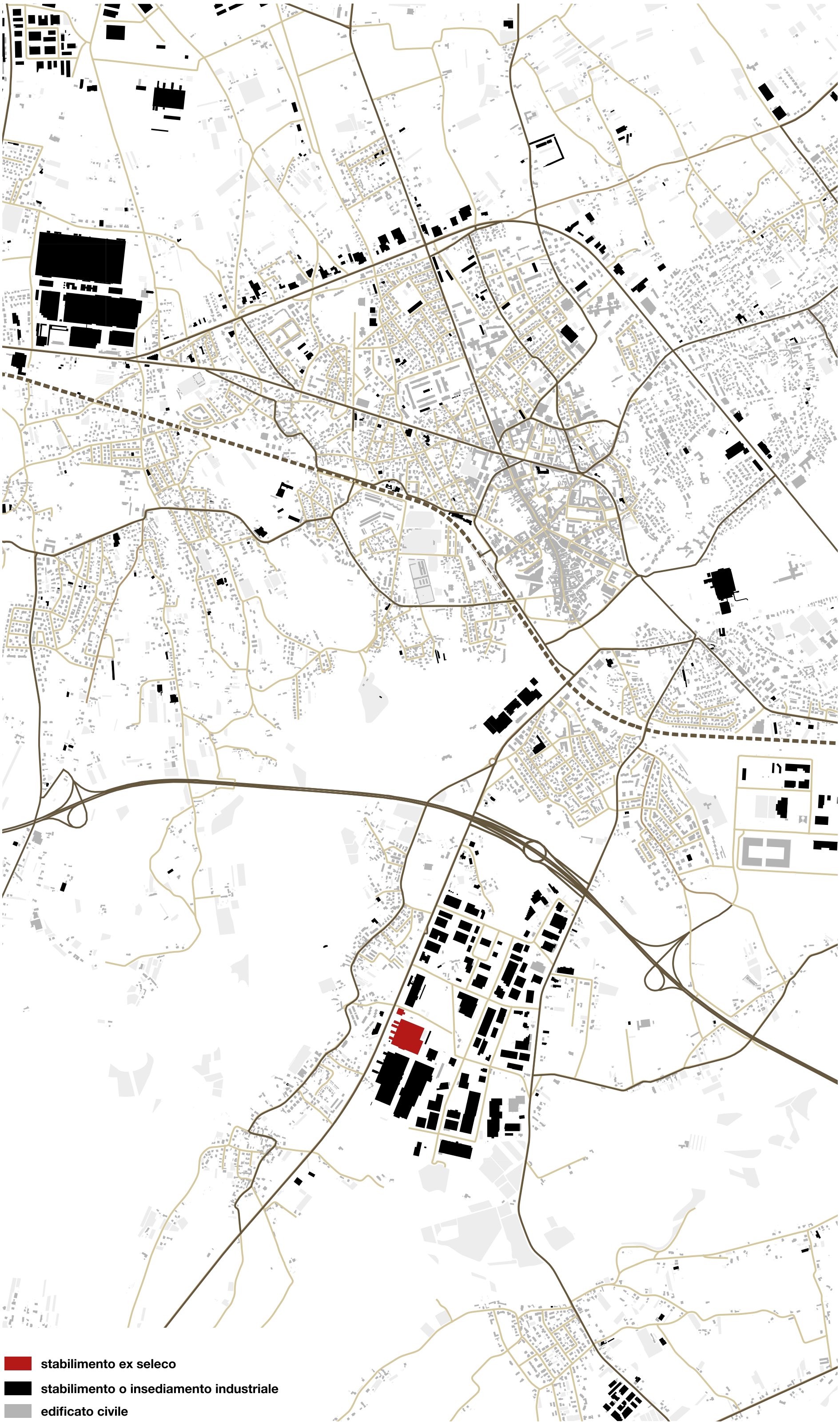
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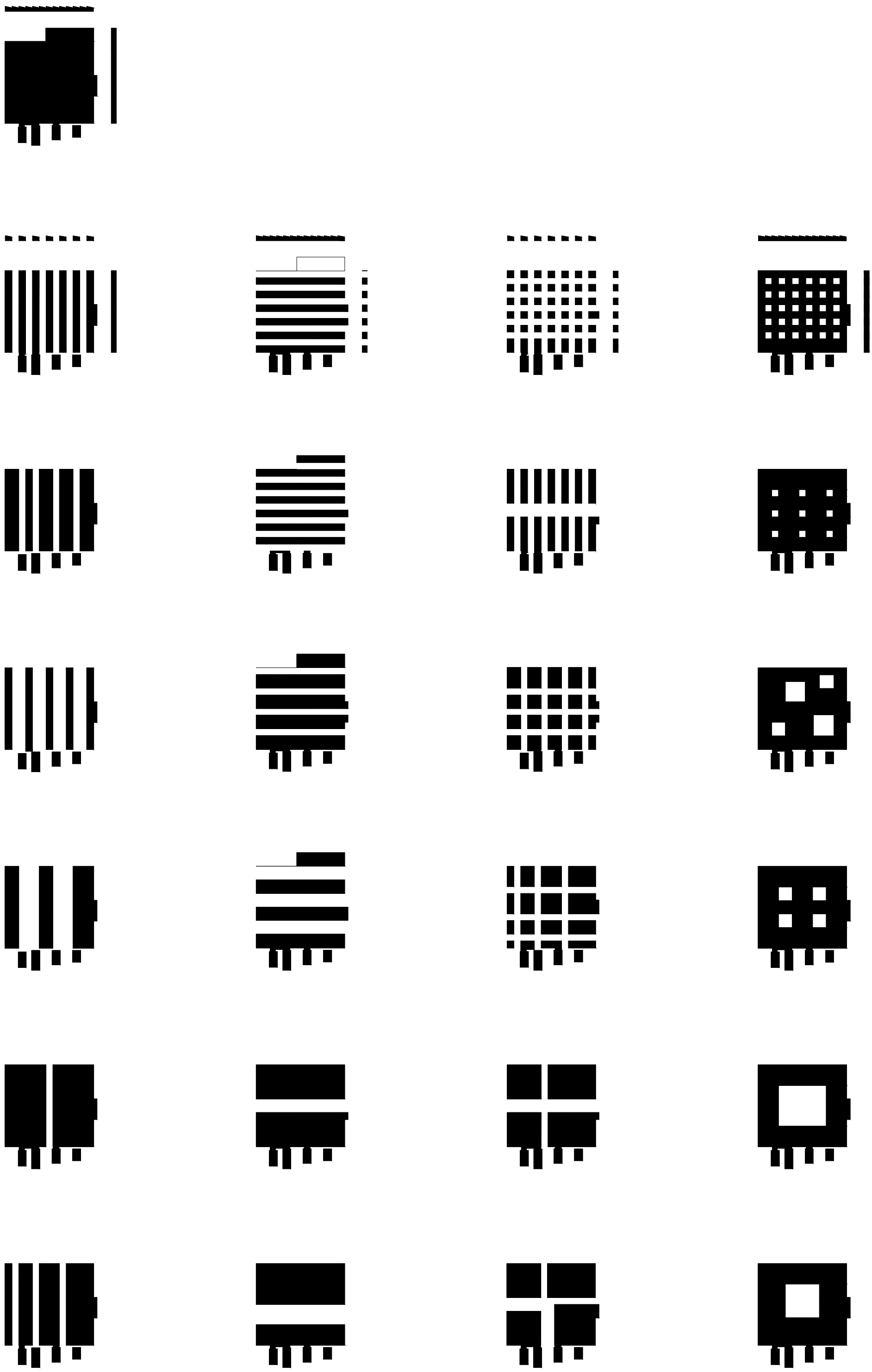
3.3.2 Form and adaptation

The Sèleco building would be suited to many of the above-mentioned uses but its huge scale - in terms of both areas and volumes - implies the identification of adequate solutions for its adaptation in order to serve the new uses as well as the current requirements (in terms of daylight, ventilation, circulation patterns etc.). Several plan reorganisation and architectural adaptations have been envisaged to illustrate the scenario of possible alterations of the building. The possible solutions explores various degrees of 'fragmentation' of the original block, keeping the span as the basic module:

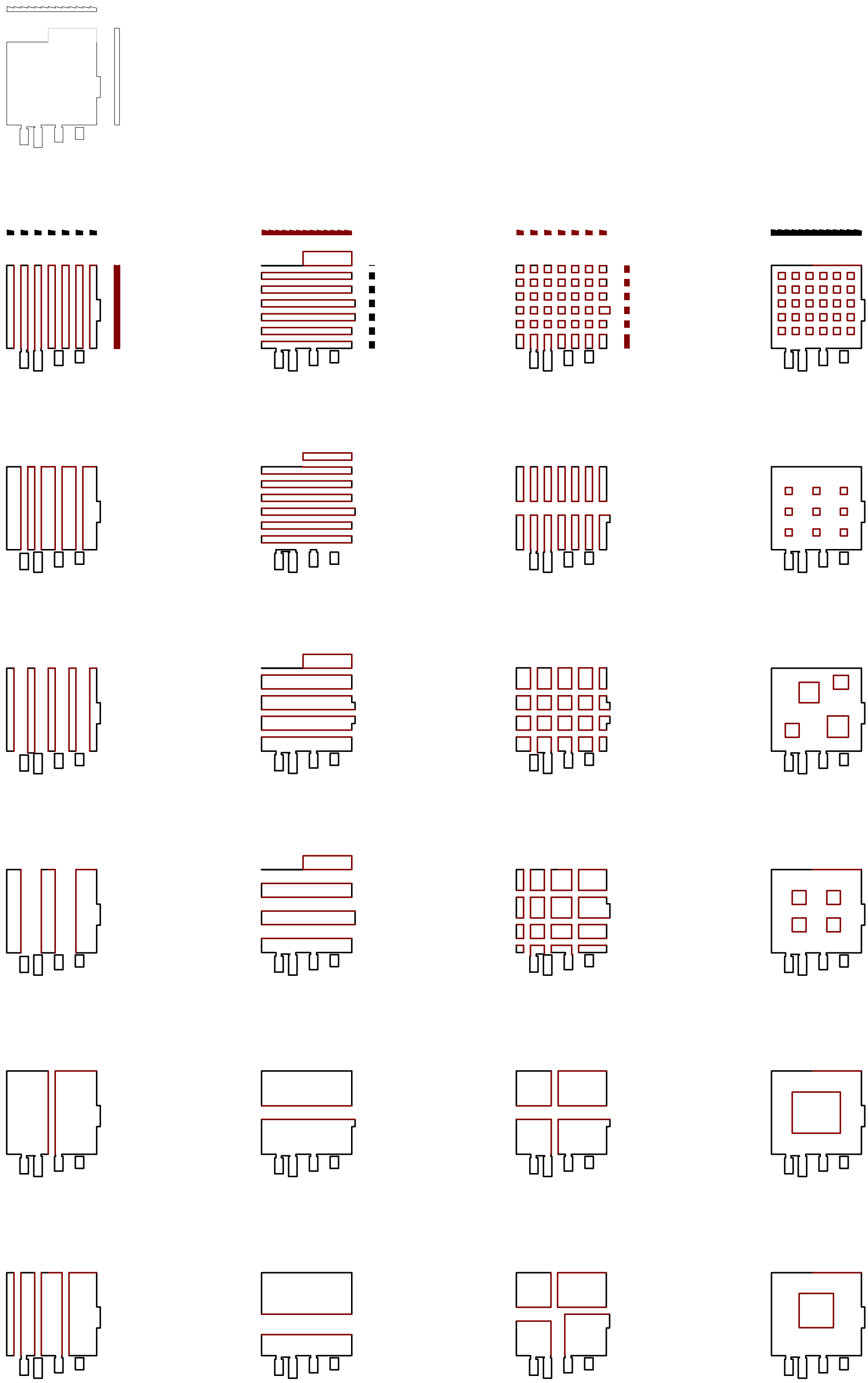
subdivision: splitting the building into two or more parts, longitudinally or transversely, and creating a number of long autonomous spaces with various dimensions and available surfaces;
fragmentation: subdivision of the building in both directions, creating even smaller new units;
subtraction: creating courtyards and patios inside the original perimeter of the building.

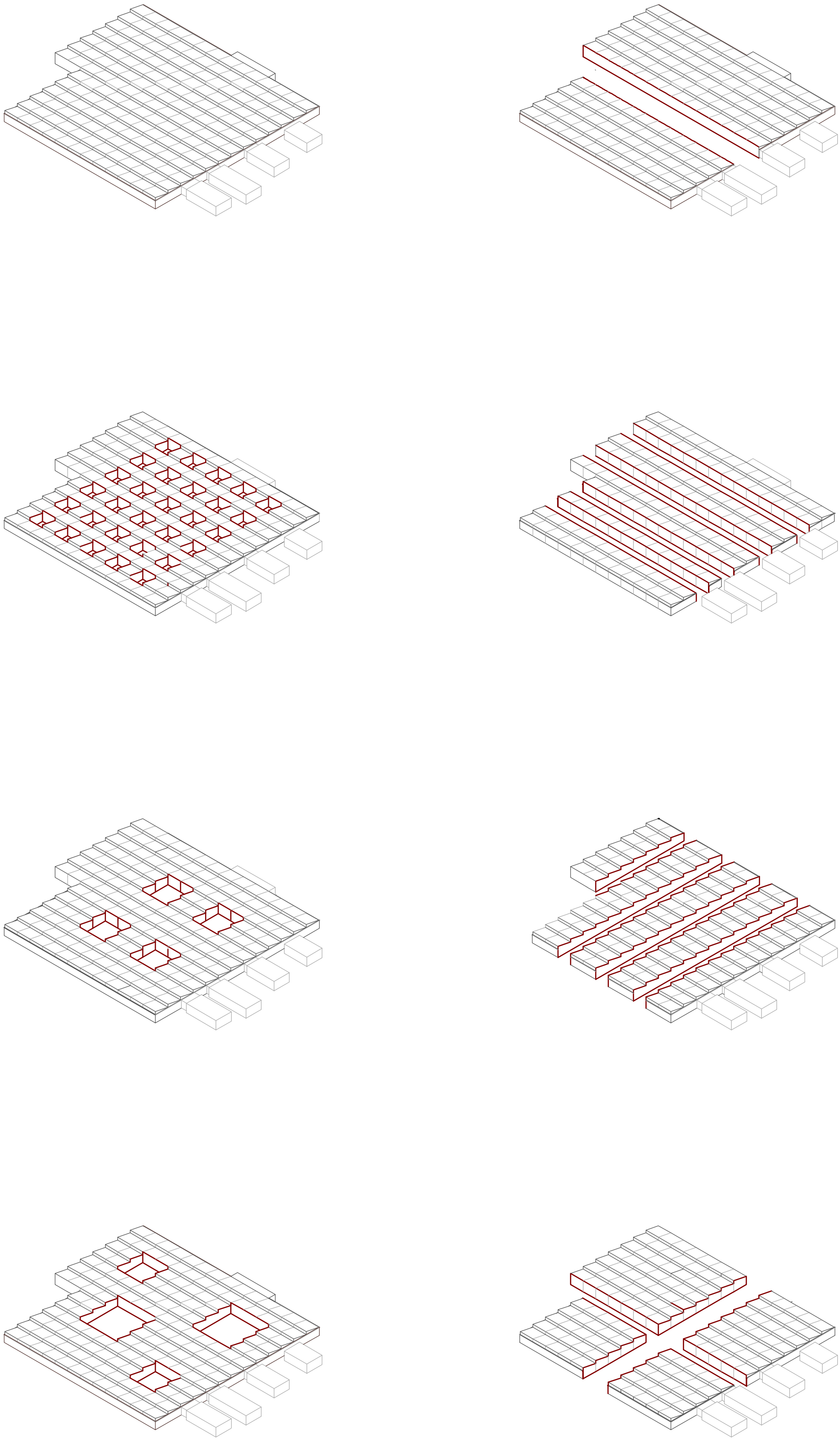
As a consequence, the building's existing façade would need to be adapted and the provision of new parts of building envelope would be required. Thus the study proposes a set of technological solutions and components to be used for creating this new cladding.

FORM ADAPTATIONS



FAÇADE ADAPTATIONS





3.3.3 Functional, structural, and energy performance upgrade: intervention criteria

From a performance perspective, the work on the building must be seen as technological solutions necessary to meet specific requirements, defined according to the needs of individuals who use the facility. In accordance with standards[166] the user's needs could be summarised in seven classes of requirement: safety, comfort, usability, appearance, management, integration and environmental safeguarding.

The first element of evaluation should be the analysis of the structure and its condition, through static and seismic verification of both vertical structures and foundations, in order to determine how much and which renovation work is effectively sustainable by the existing structure.
The non-structural elements must be adequately verified for both static and seismic actions, as they can affect the safety of users as well as the behaviour of the overall structure (chapter 2). In particular, secondary elements such as panels, ring beams and cladding elements, while not compromising the stability of the structure, may be harmful to users in the event of their collapse, detachment or falling material, and should be properly anchored. However, technological solutions for upgrading and securing connections should not significantly alter the original appearance of the building.
In the Sèleco building, the metal structure requires the assessment of vertical loads to determine its ability to support the proposed adaptations and additions, such as additional floors and ceilings or new roof components such as covering, insulation layers or solar photovoltaic panels. A specific assessment is needed for the precast concrete cladding panels, also on account of their weight[167] and the uncertain level of deterioration of concrete and corrosion of the connections.

The implementation of strategies for compliance with other regulatory requirements concerns issues such as security, fire prevention, accessibility, and the identification of design and technical solutions suitable for this purpose and compatible with the characteristics of the building. The measures adopted range from the provision of adequate compartmentalisation and fire-escapes to the removal of architectural barriers etc., aspects which were considered in the development of the solution proposed.

[166] UNI 8289: 1981 Edilizia. Esigenze dell' utenza finale. Classificazione.

[167] Panel wide version, 105 cm wide, 7 m high, concrete mass 0,610 m3, estimated weight of the panel 1490 kg; panel narrow version, 75 cm wide, 7 m high, concrete mass 0,430 m3, estimated weight of the panel 986,7 m3; façade consisting of 13+3 panels, length 12.5 m, weight 21277 kg.

Additionally, growing awareness of the problem of dangerous and hazardous materials in buildings has brought to light new issues regarding industrial spaces.
In particular, the twentieth century was in fact marked by the appearance of two long-lasting materials with outstanding technical properties that at first appeared to have no disadvantages: asbestos and PCB. After a couple of decades of the use of these two materials - the former being of natural and the latter of artificial origin - serious health issues were found in people working in and using buildings in which these materials had been used. As a consequence the production and use of these materials was banned. In both new construction and in renovation work the use of such materials, which were subsequently proven to be hazardous, reached a peak between 1930 and 1980. Today, in the event of demolition or renovation work, multiple inspections are required before building work starts to establish whether materials such as asbestos are present.
Further examples of such new hazardous material can be seen in the case of lead in anti-rust paint or the bonding agents used to produce wood and plywood panels: the glues may release high levels of hazardous gas such as formaldehyde.
The presence of radon in buildings is also a particular concern, given that industrial buildings - and generally buildings from the period - were usually built with unventilated ground floors.

Thermo-hygrometric aspects have the greatest impact upon the well-being of the users of the facility and generally a series of adaptation initiatives of the building envelope is necessary in order to upgrade the building to current performance standards. In order to reduce the heat-loss, which not only affects the consumption of resources but also the achievement of a suitable temperature of the interior space, interventions generally include measures of improvement of the energy efficiency of all the elements of the building envelope, also through the replacement.
The energy retrofit is intended to maintain the original external appearance of the façade (geometric and material), operating on the interior side with a new insulation package. The analysis of the building elements suggested the replacement of external openings (doors, gates, loading/unloading mouths, and skylights) - elements which, while maintaining the original appearance as much as possible, will have to guarantee the required transmittance values and be air-tight.
Current regulation calls for specific values regarding the performance of the building envelope, including standards on the thermo-hygrometric properties of building materials[168] and technical specifications of the assessment methodology[169]. In detail, in the Italian context, a series of Ministerial Decrees on energy efficiency compose the regulatory framework on energy efficiency in building[170]; the regulation defines the

[168] UNI 10351:2015 proprietà termoigrometriche dei materiali da costruzione.

[169] UNI/TS 11300 technical standards on the energy performance of buildings including, part 1-6.

[170] Decreto 26 giugno 2015, adaptation to European Commission Directive 31/2010/UE, includes minimum requirements, certification of energy performance of buildings (APE).

intervention criteria and applicability of the minimum requirements for existing buildings subject to renovation works (first or second level) or energy efficiency upgrades. As regards the proposed transformation of the Sèleco building, the percentage of modification on the existing building envelope will be less than 25% thus in the category of “energy efficiency upgrade”.

The minimum requirements for energy retrofits consists in specific values for the characteristic parameters of the building elements and systems. As for the building envelope components, the significant parameter is the minimum thermal transmittance (U-value)[171], according to the climate area[172]. As regards the periodic thermal transmittance (Yi,e) evaluating the ability of an opaque wall of phase-shifting and attenuating the periodic component of the heat flux which crosses over 24 hours[173]. The building envelope must also meet the requirements to avoid overheating in summer, having as a benchmark the value of total solar transmittance of the windowed components with East-South-West orientation.

Thus a preliminary assessment of the energy performance of the building envelope of the Sèleco building has been carried out. de

Energy performance of the façade:

	thickness s [m]	density ρ [kg/m^3]	Thermal conductivity λ [W/mK]	specific heat capacity c [J/kgK]	water vapour resistance μ [-]	surface mass M_s [kg/m^2]	thermal resistance R [m^{2}K/W]	thermal transmittance U [W/m^{2}K]
outside surface							0,04	
precast concrete panel	0,105	2200	1,677	878,6	100	231	0,06	
inside surface							0,13	
stationary parameters	0,105					231,0	0,23	4,30

dynamics parameters	periodic thermal transmittance Yie [W/m^{2}K]	attenuation factor	time shift
winter values	3,70	0,86	2h 30'
summer values	3,01	0,70	3h 2'

winter assessment: not verified, thermal transmittance 4,299 W/m^{2}K > limit value 0,3 W/m^{2}K

summer assessment: average irradiance in the maximum insulation month: 267,5 W/m^2 < 290 W/m^2 (dynamic assessment not required)

verification of surface condensation: the structure does not comply; interstitial condensation: not present.

[171] The minimum U-values [W/m^{2}K] for the Climate zone E (Pordenone) for the year 2015 and 2012 are: walls: 0,30 - 0,28; roofs: 0,26 - 0,24, floors: 0,31 - 0,29, windows: 1,90 - 1,40.

[172] Climate data for Pordenone (PN): climate zone E, 2385.45168539323 degree days.

[173] Yi,e as defined and determined in accordance with the UNI EN ISO 13786: 2008 and subsequent updates; the decree provides for walls Ms > 230 kg/m^2 or Yi,e [W/m^{2}K] ≤ 0,10, and for roofs and floors Yi,e [W/m^{2}K] ≤ 0,18.

Energy performance of the roof:

	thickness s [m]	density ρ [kg/m³]	Thermal conductivity λ [W/mK]	specific heat capacity c [J/kgK]	water vapour resistance μ [-]	surface mass M_s [kg/m²]	thermal resistance R [m²K/W]	thermal transmittance U [W/m²K]
outside surface							0,04	
aluminium sheet	0,008	2700,0	220,000	962,3	2000000	21,6	0,00	
mineral wool	0,120	100,0	0,037	836,8	1,2	12,0	3,24	
galvanised steel corrugated sheet	0,008	7800,0	52,000	460,2	2000000	62,4	0,00	
inside surface							0,10	
stationary parameters	0,136					96,0	3,38	0,30

dynamics parameters	periodic thermal transmittance Yie [W/m²K]	attenuation factor	time shift
winter values	0,28	0,94	2h 36'
summer values	0,26	0,87	3h 16'

winter assessment: not verified, thermal transmittance 0,296 W/m²K > 0,26 W/m²K
summer assessment: average irradiance in the maximum insulation month: 267,5 W/m² < 290 W/m²
(dynamic assessment not required)
verification of surface condensation: the structure complies; interstitial condensation: condensation is present

Energy performance of the ground floor:

	thickness s [m]	density ρ [kg/m³]	Thermal conductivity λ [W/mK]	specific heat capacity c [J/kgK]	water vapour resistance μ [-]	surface mass M_s [kg/m²]	thermal resistance R [m²K/W]	thermal transmittance U [W/m²K]
outside surface							0,04	
filling - medium quality	0,200	1500,0	0,700	1000,0	1,0	300,0	0,29	
ordinary concrete screed	0,100	2000,0	1,060	1000,0	1,0	200,0	0,09	
inside surface							0,17	
stationary parameters	0,300					500,0	0,59	1,69

dynamics parameters	periodic thermal transmittance Yie [W/m²K]	attenuation factor	time shift
winter values	0,42	0,25	9h 46'
summer values	0,50	0,30	9h 43'

winter assessment: not verified, thermal transmittance 1,695 W/m²K > 0,31 W/m²K

Additionally, measures for the direct and indirect use of solar energy might be included in the project, resulting in a wide range of strategies. Direct use depends on those specific building features (i.e. the creation of new transparent openings and their shape and orientation) for regulating the interior climate and the energy balance, which embrace the fundamental principles of solar heating and utilisation of daylight. Moreover, additional measures might be aimed at collecting, distributing and storing solar energy (indirect use). Solar collectors for both hot-water heating and space heating and photovoltaic systems to produce electricity might be integrated to the building envelope - especially the roof, given the surface inclination and its orientation south-west.

The design and technical solutions to ensure adequate usability of the building and to meet regulatory requirements must pay special attention to issues related to accessibility. Besides the intended final use of the building, in fact, given the presence of public spaces, the environment must be totally accessible. Intervention must therefore consider, on the one hand, the provision of adequate safety measures and the removal of architectural barriers, and on the other, the overall improvement of the space according to current concept of ‘design for all’.

Given the generally good condition of the site, the intervention is aimed primarily at its functional adaptation and is meant as an opportunity to restore the original appearance of the building, which in the last decades has seen quite substantial additions on the entire perimeter, without, however, compromising existing components.

The restoration and preservation of its original aesthetic is favoured by the prior analysis of the building, in its dimensional and material elements, which allows the definition of which solutions are ‘acceptable’ for the case. From this perspective, the current approach is to remove the most recent changes (mainly shelters, fixtures and plaster work) and to restore the previous condition, taking care to maintain the geometric order of the façades and restore the chromatic and material aspects where they have been altered.

The intervention on the concrete elements primarily concerned the removal of the signs of alteration and decay of the materials, in order to stop or limit their development and to restore the original surface appearance (clean-up operations and small repairs, while replacements do not seem necessary - there are no damaged panels).

The integration of new elements in the existing façade, such as the replacement of panels which may be damaged in the future, must take account of the original façade design in respect of modularity and the specific assembly system.

Moreover, as regards the of maintenance and restoration of the original substance, it is preferable to address choices towards a single type for the openings (doors, windows and especially the loading/unloading doors), which will be similar to the originals but with technological features to fulfil current requirements of thermal transmittance and air-tightness.

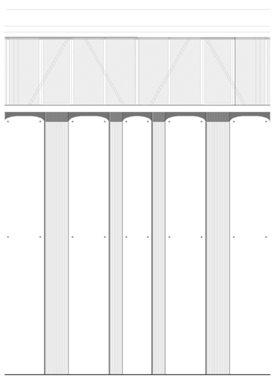
In the event of future works on the roof, it would be preferable to maintain the existing geometry (sloping) and the same type of roof covering, in order to avoid altering the dimensional relationship between the parts, both in the proportions of the façade and in the interior space.

The proposed solutions are intended also to improve aspects of management and integrability.
Finally, in its pursuit of an energy-efficient upgrade of the building as well as its functional and aesthetic improvement, the intervention is coherent with the principles of sustainability and the necessary attention to the environmental protection.

3.3.4 Transformation and adaptation of the building envelope

As the building's existing façade would need to be adapted and the provision of new parts of building envelope would be required, a set of technological solutions and components to be used for creating this new cladding are proposed.

a. energy retrofit
b. additions and replacements: openings
c1. new façade: transparent elements
c2. new façade: shading devices
d. new façade: solid/opaque elements
e. new façade: textile elements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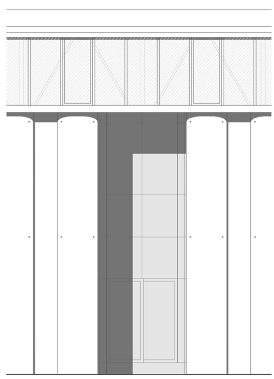
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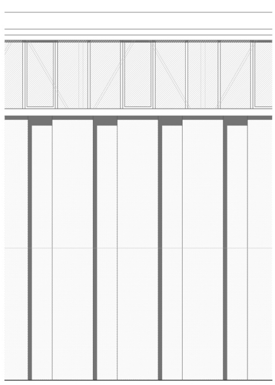
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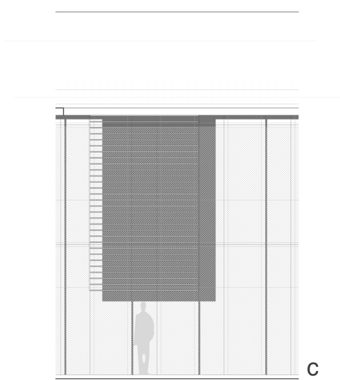
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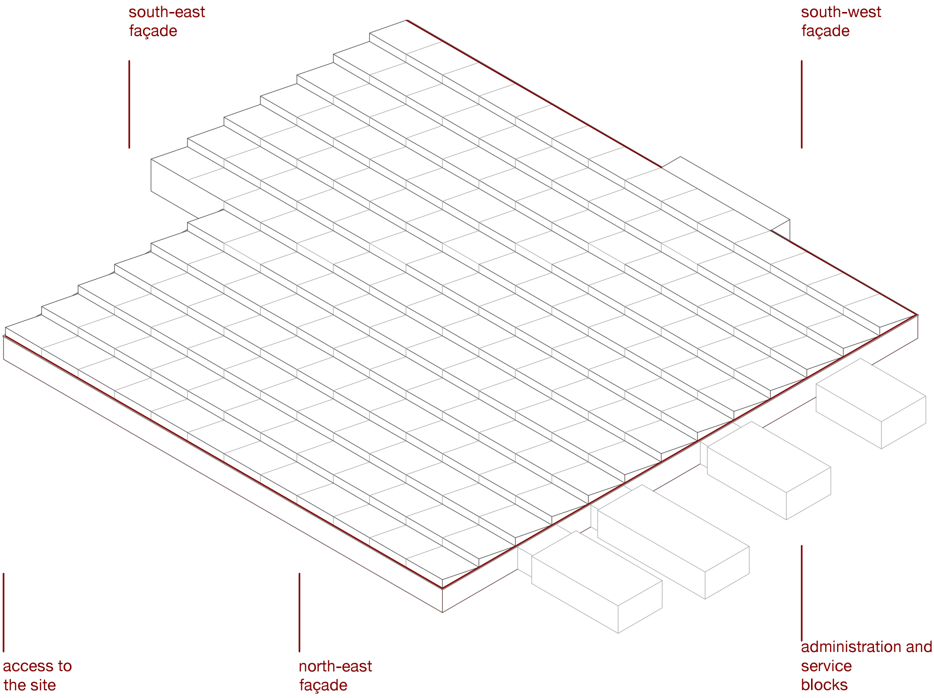
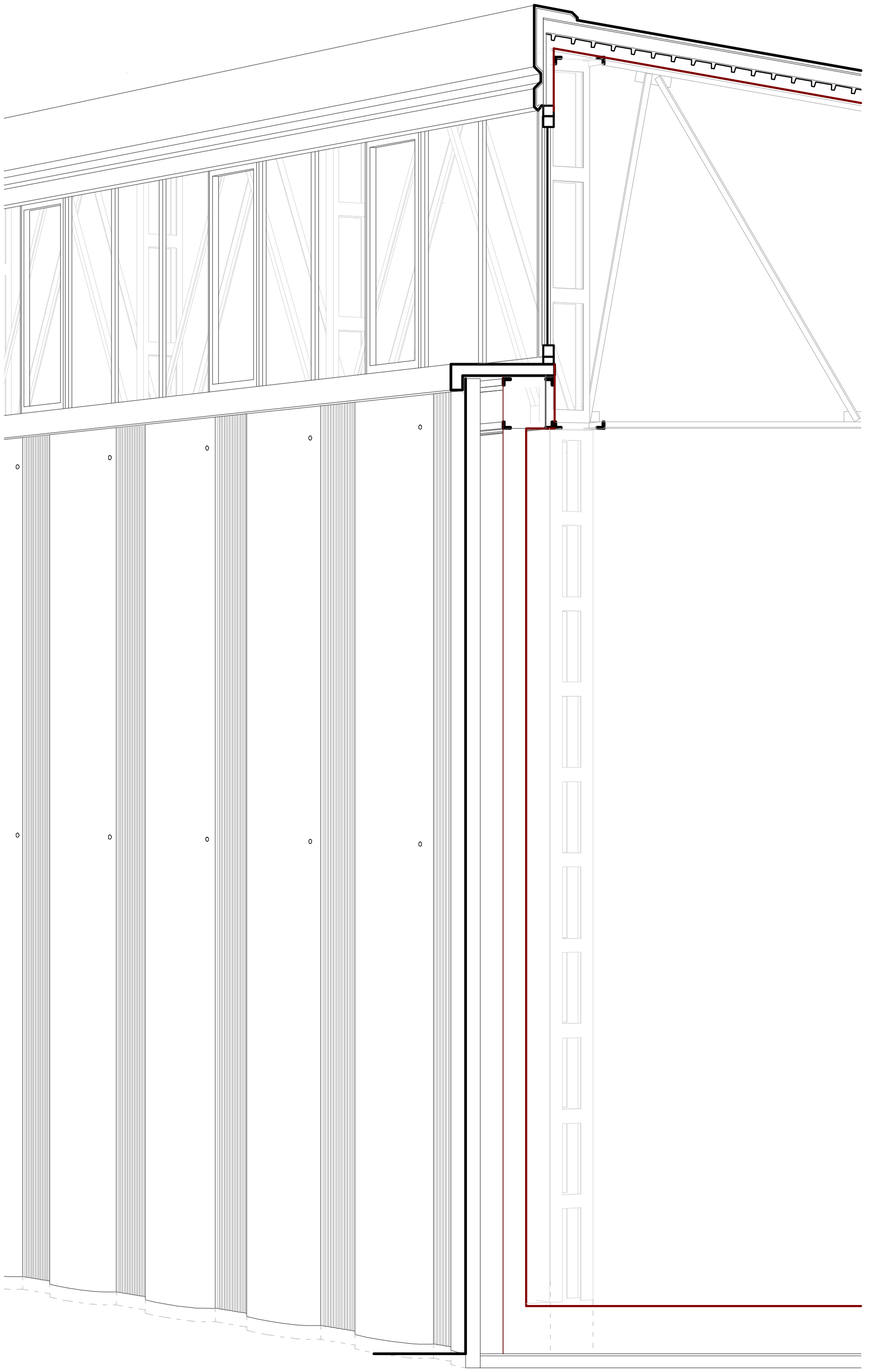
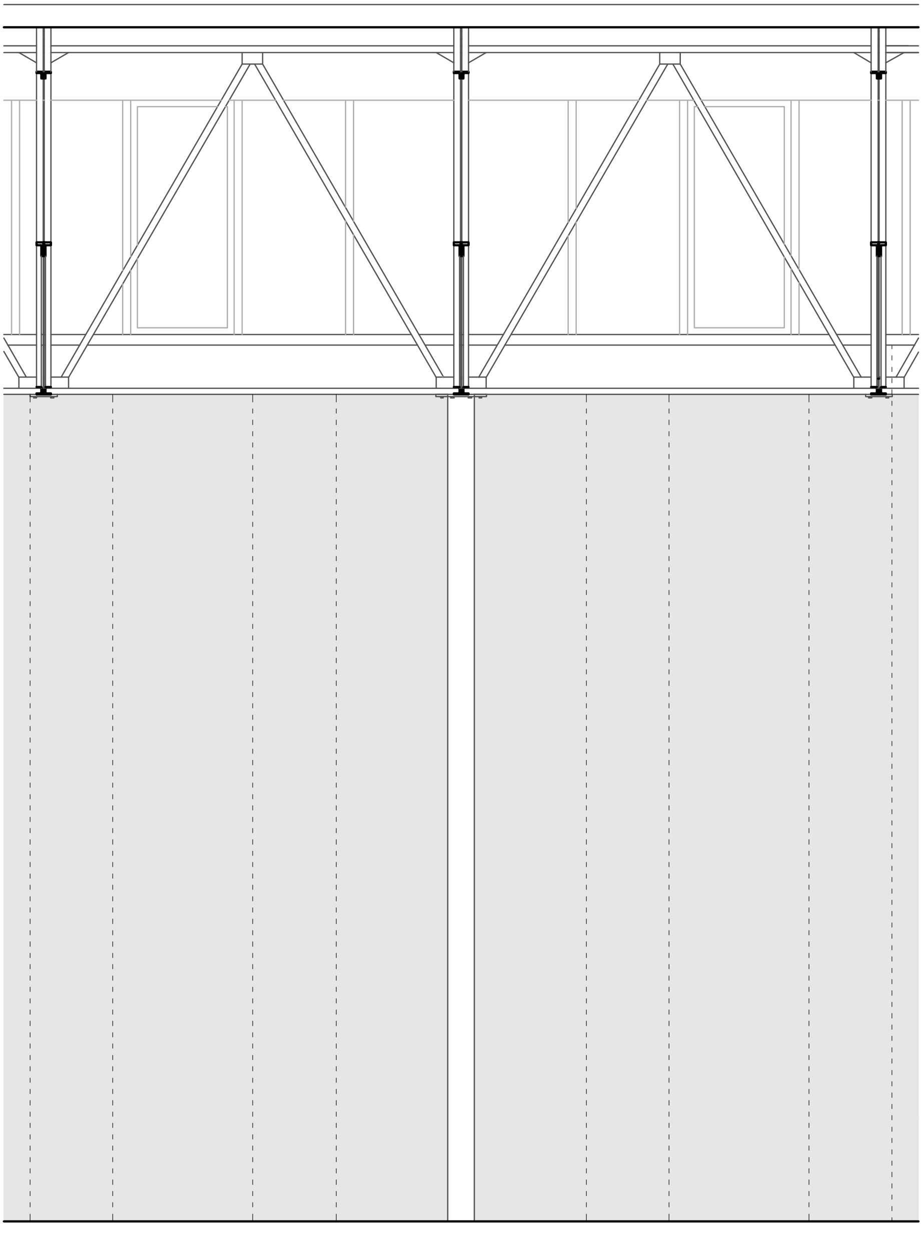
a. energy retrofit





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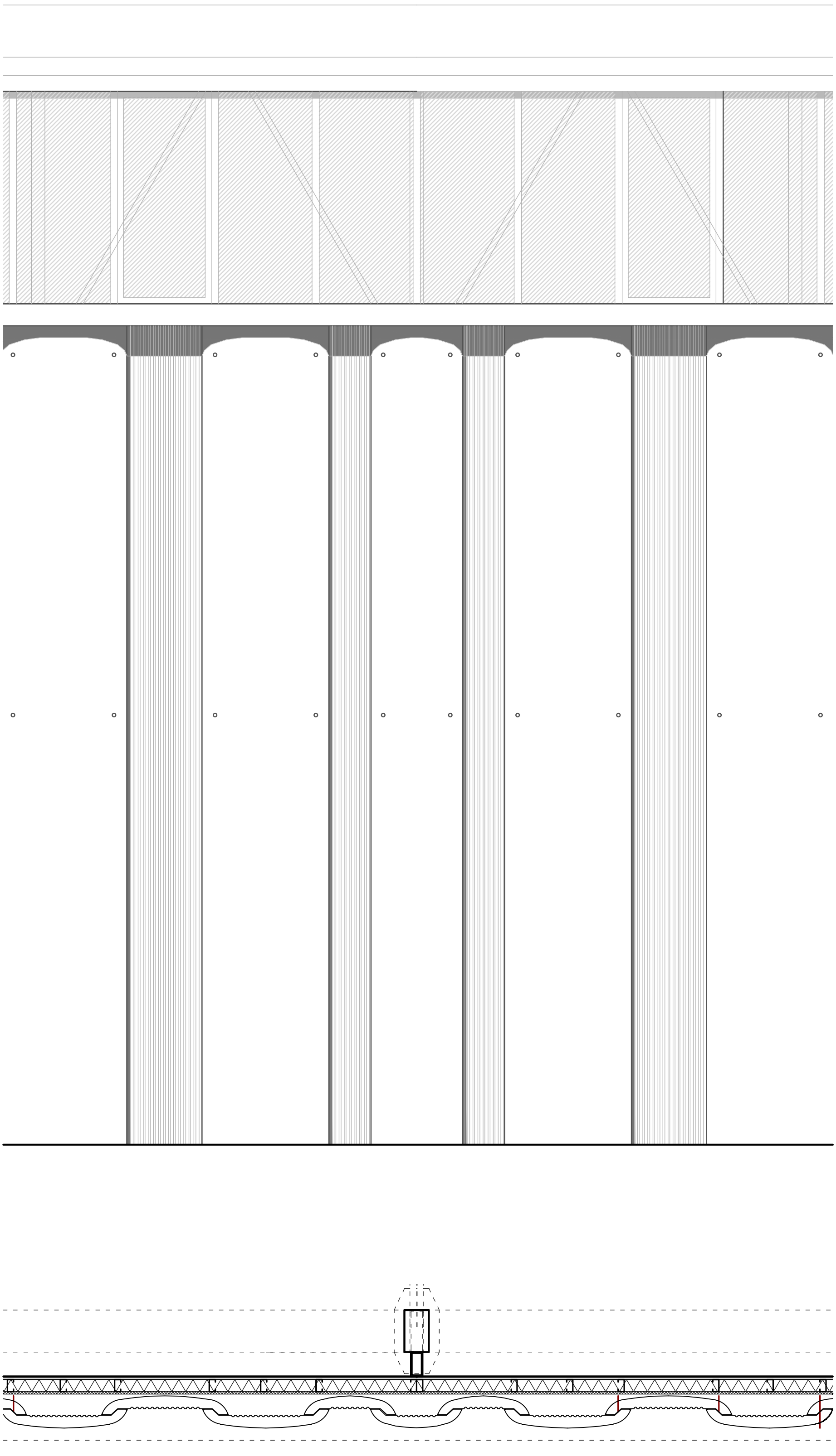


walls: energy efficiency upgrade

specification

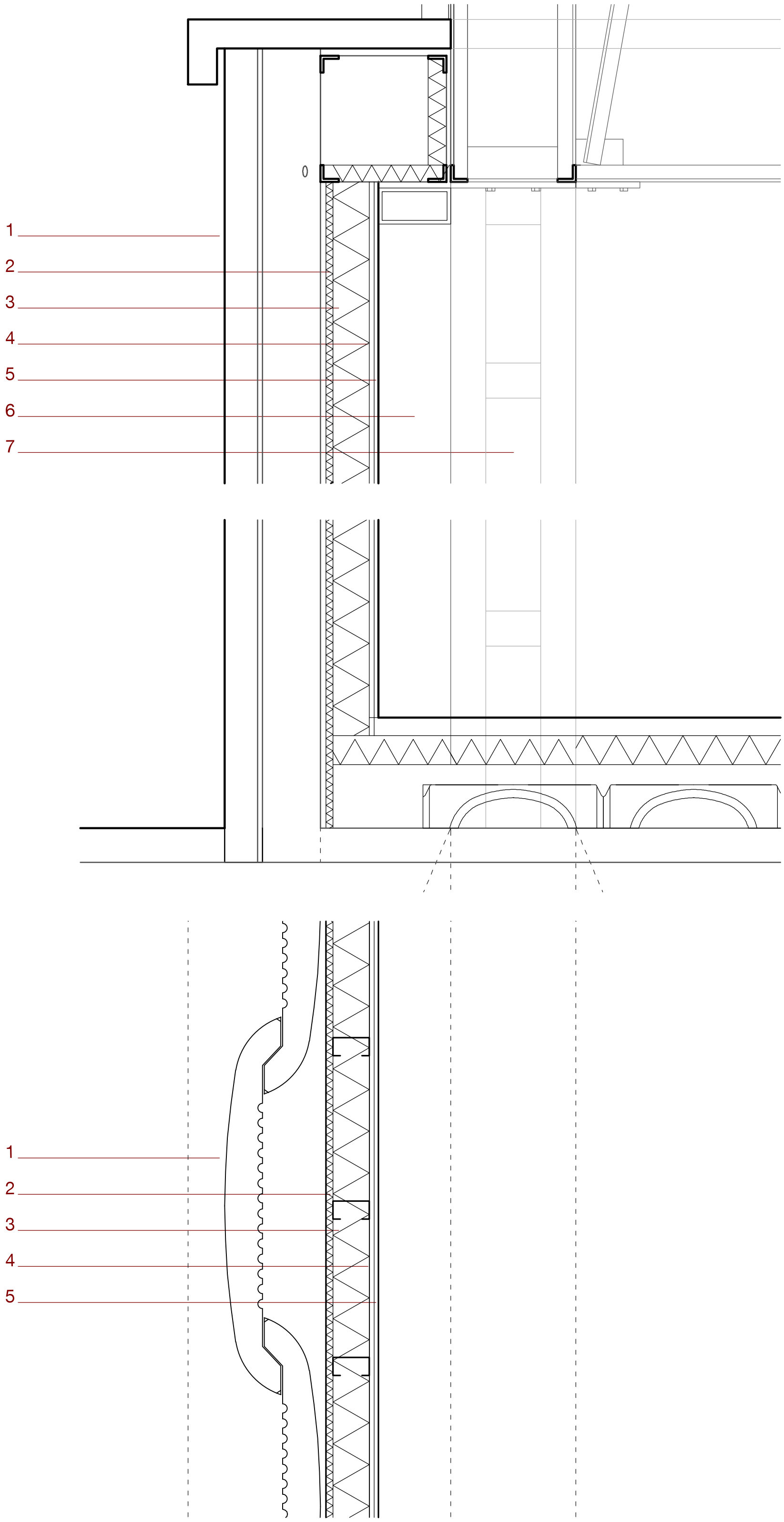
1 façade panel, precast concrete, 105 mm
2 supporting structure, double gypsum board, 25 mm
3 insulation layer, high density rock wool panel, 120 mm
4 vapour barrier, coated aluminium sheet, 0.08 mm
5 wallboard, double gypsum board, 25 mm,
6 supporting structure
7 bearing structure, metal pillars

energy performance assessment

		thickness s [m]	density ρ [kg/m^3]	Thermal conductivity λ [W/mK]	specific heat capacity c [J/kgK]	water vapour resistance μ [-]	surface mass M_s [kg/m^2]	thermal resistance R [m^{2}K/W]	thermal transmittance U [W/m^{2}K]
	outside surface							0,04	
1	precast concrete panels	0,105	2200	1,677	878,6	100	231	0,06	
2	gypsum board	0,013	900	0,21	836,8	8	11,3	0,06	
3	rock wool panel	0,12	70	0,035	1046	1	8,4	3,43	
4	aluminium sheet covered 0.08 mm	0	2700	220	962,3	2000000	0,2	0	
5	plasterboard	0,013	900	0,21	836,8	8	11,3	0,06	
6	plasterboard	0,013	900	0,21	836,8	8	11,3	0,06	
	inside surface							0,13	
stationary parameters		0,263					273,4	3,84	0,26

dynamics parameters (south)	Trasmittanza periodica Yie [W/m^{2}K]	Fattore di attenuazione	Sfasamento
winter values	0,17	0,66	6h 6'
summer values	0,13	0,52	6h 53'

winter assessment: thermal transmittance 0,260 W/m^{2}K < reference value 0,3 W/m^{2}K
summer assessment: average irradiance in the maximum insulation month: 267,5 W/m^2 < 290 W/m^2
(dynamic assessment not required)
verification of surface condensation: the structure complies
verification of interstitial condensation: condensation not present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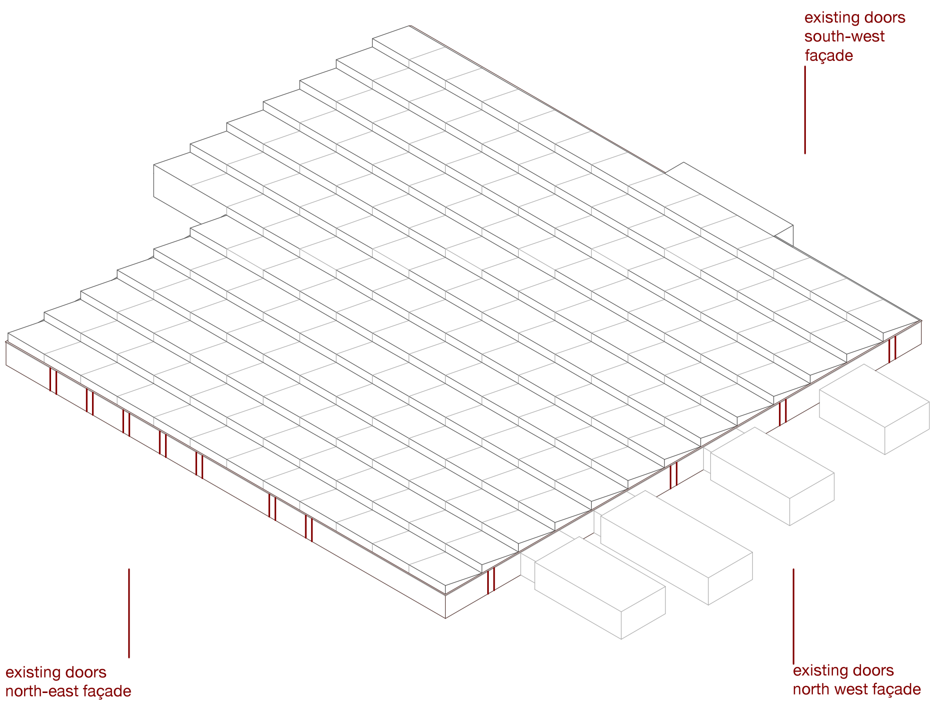
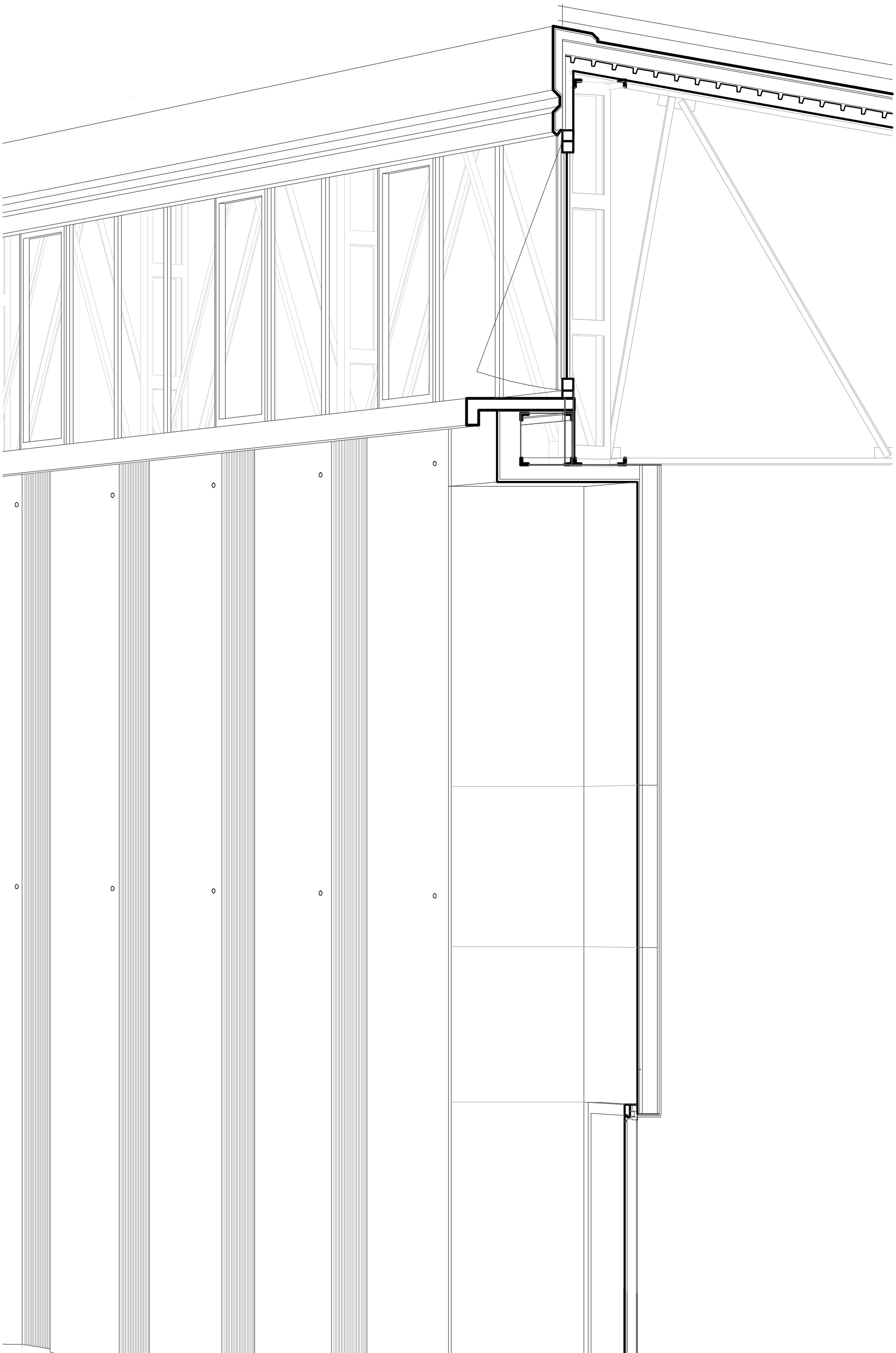
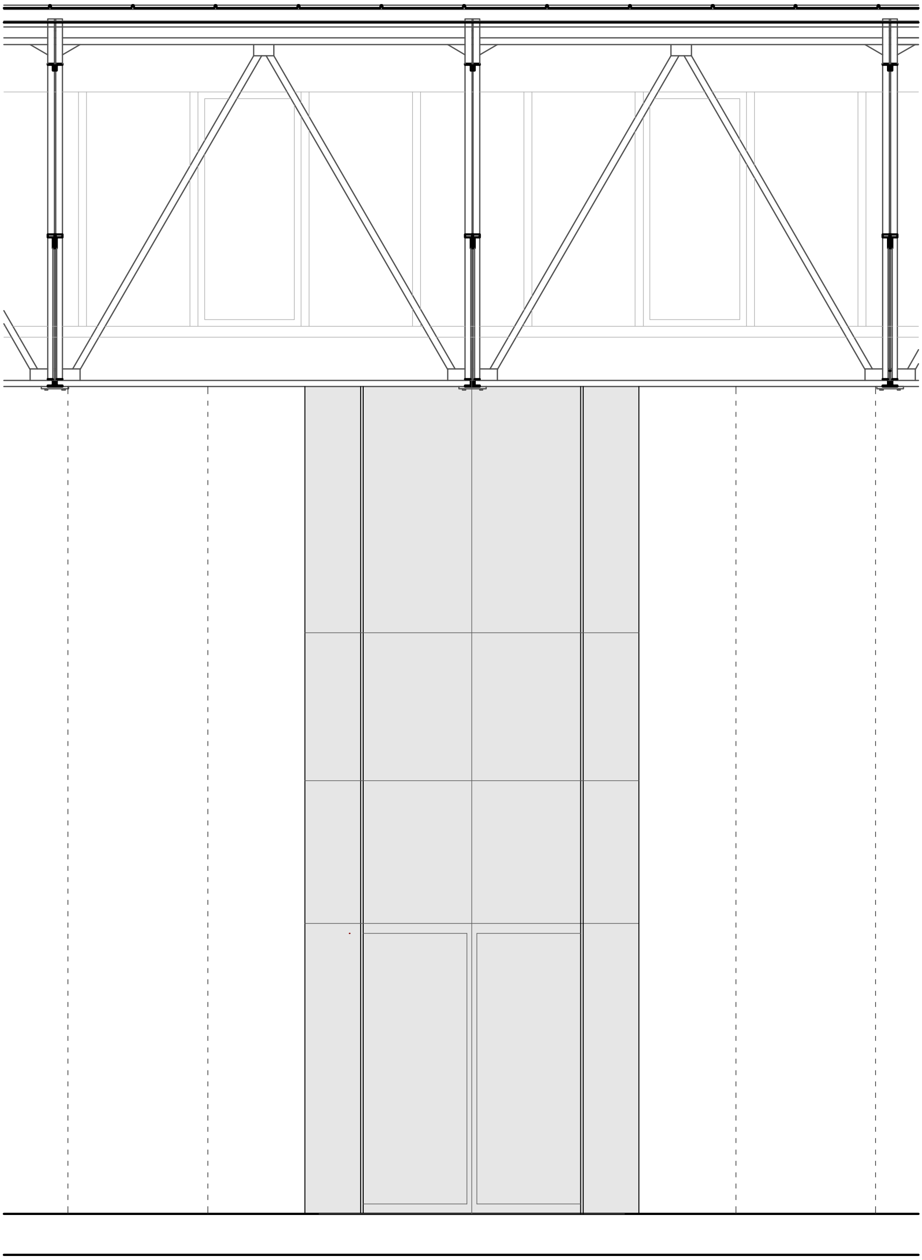
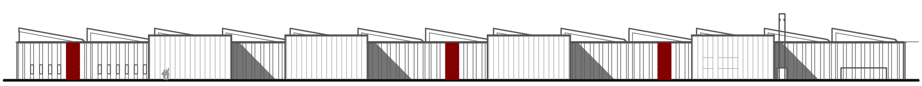
b. additions and replacements: openings

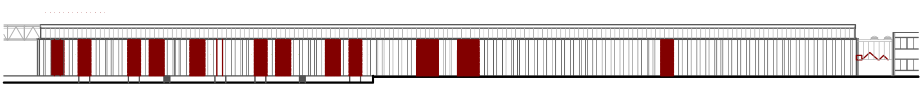
The original façade panels, given also their generally good condition, would be maintained and the replacement is envisaged only for the existing opening closure elements. The new doors are understood as new components designed and assembled according to the original modular façade system: each opening element is placed in lieu of an odd number of panels (1 or 3 or 5) so that the edge panels would be the front-facing ones.

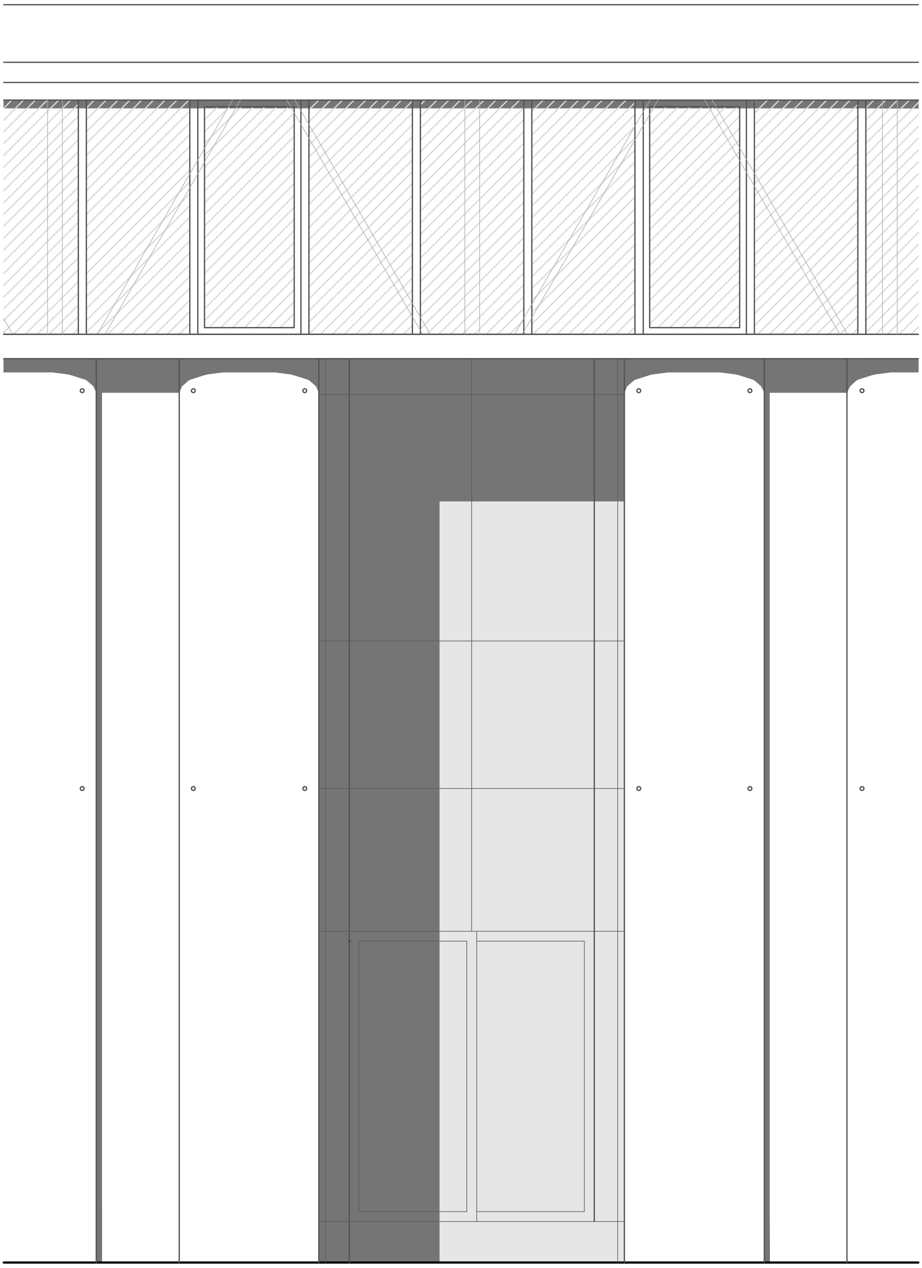


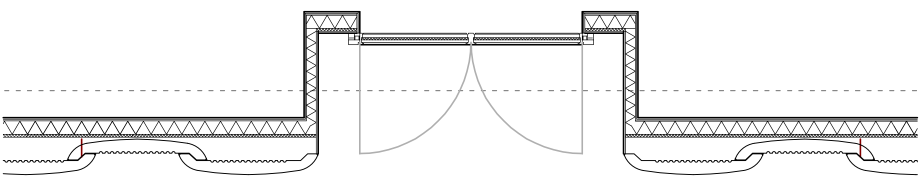


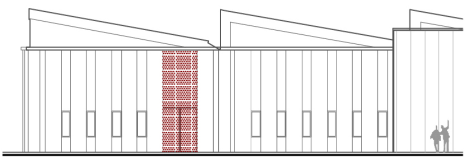


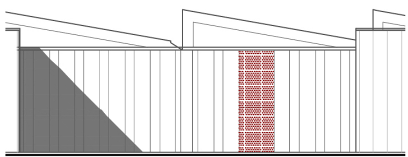


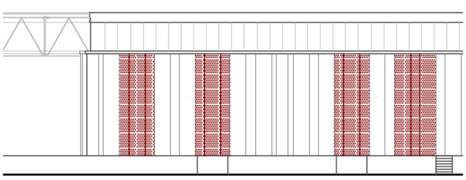


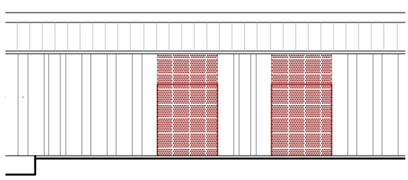


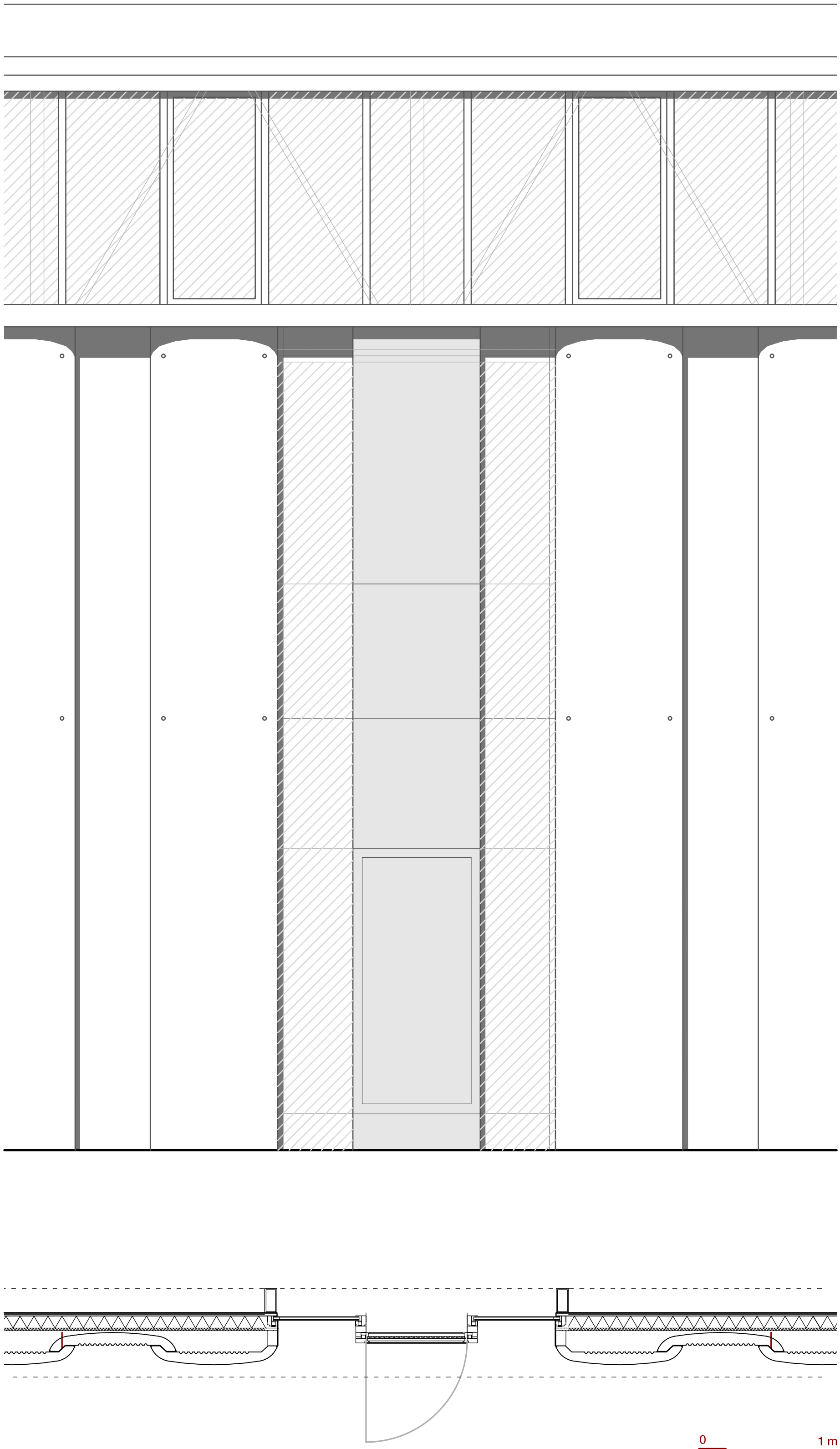








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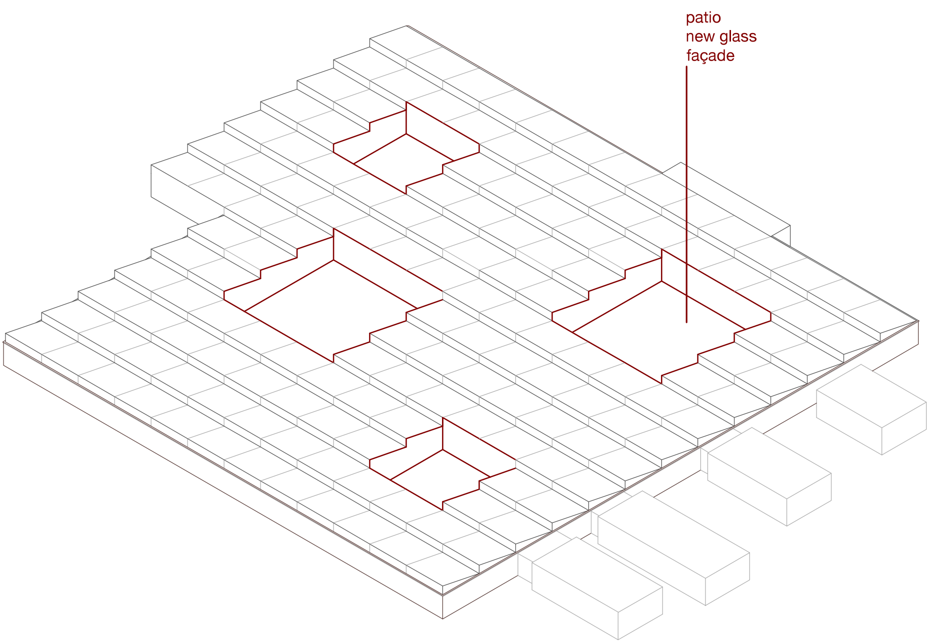
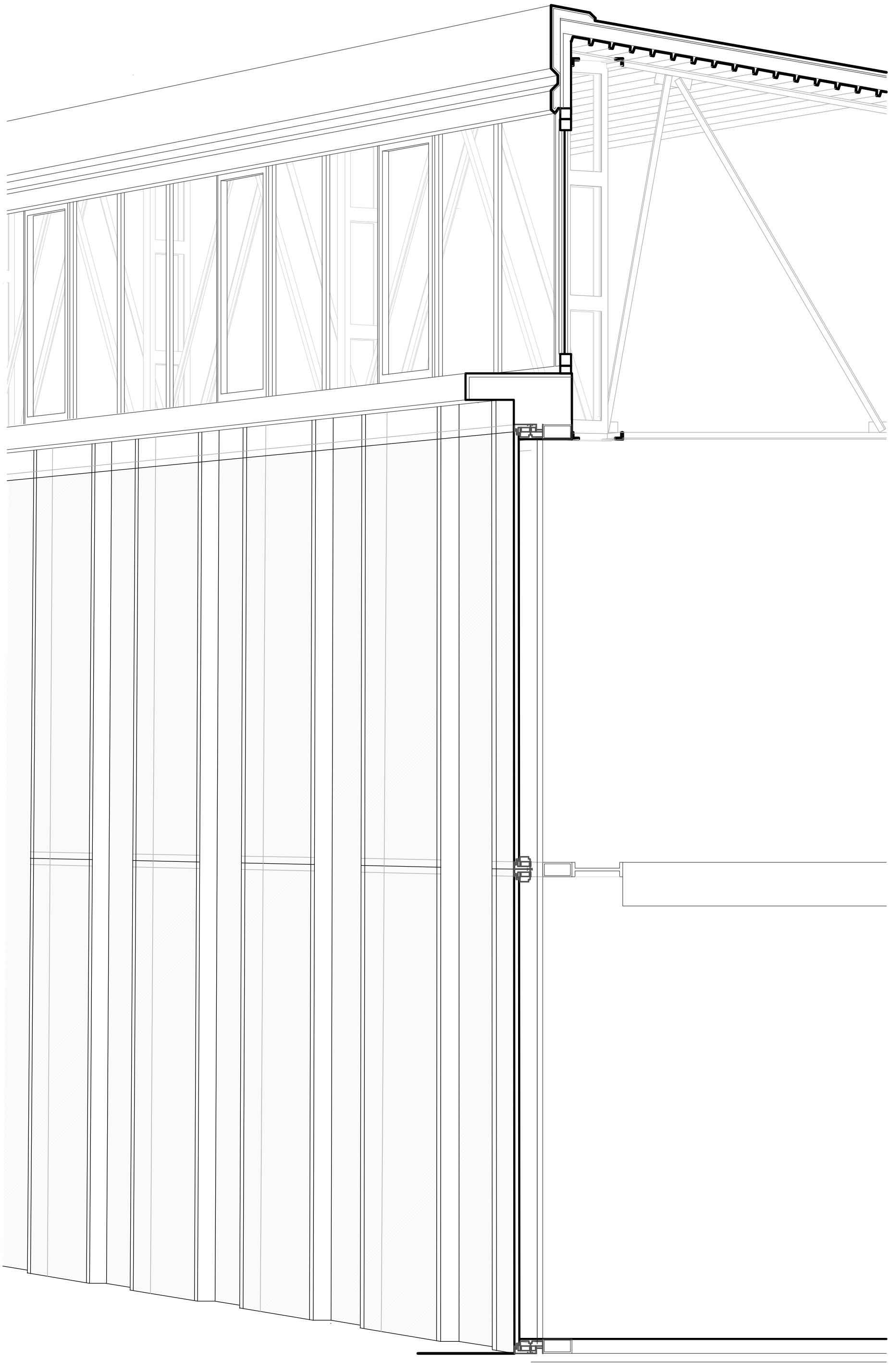
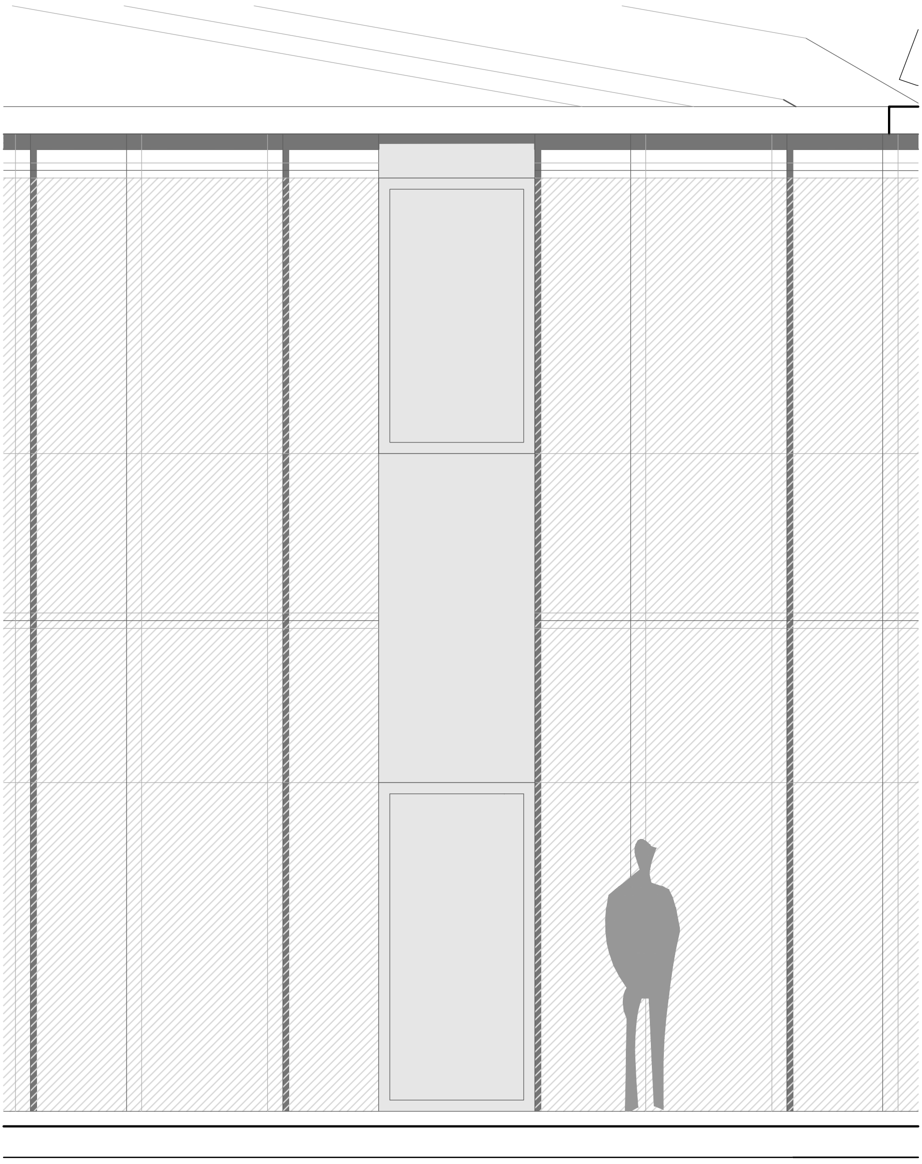
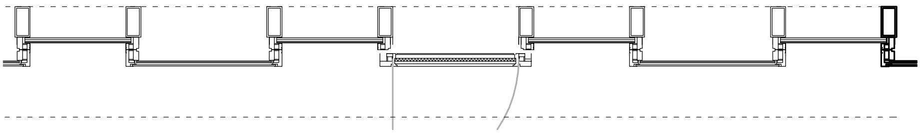
c1. new façade: transparent elements

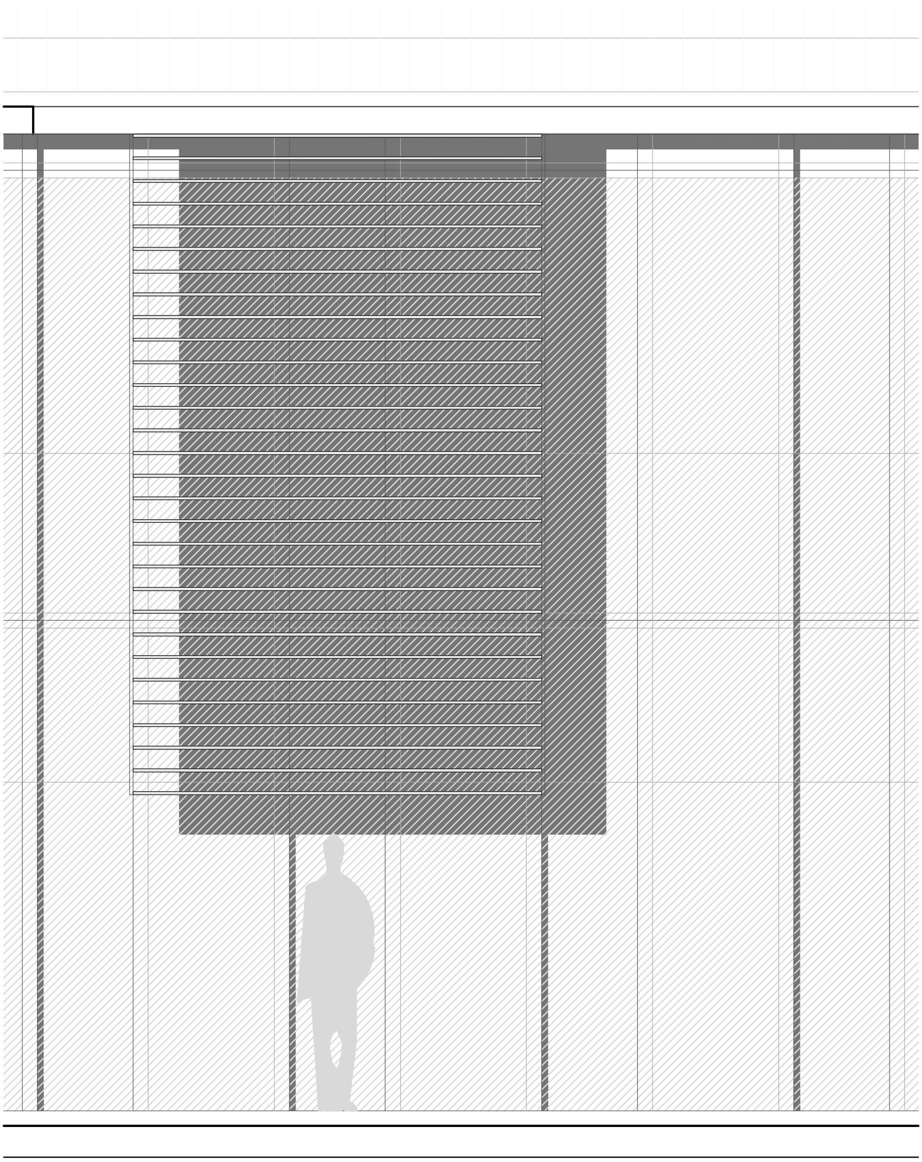
New transparent parts of the building envelope would be created in order to improve daylight and visibility of the interior space. The glazing would respect the original modular and geometrical features of the façade, using large window components, proposed in two measures which would be assembled alternating, as the original precast concrete panels.

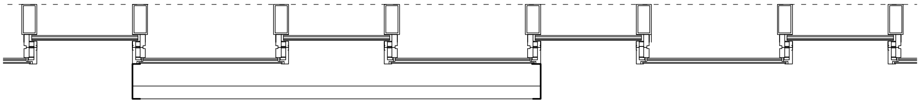






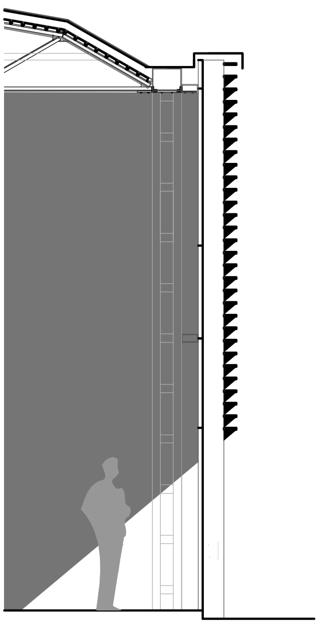


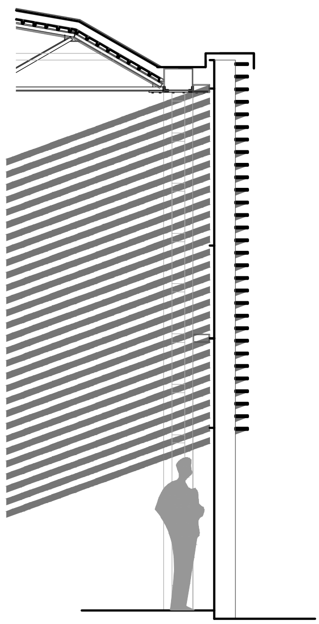


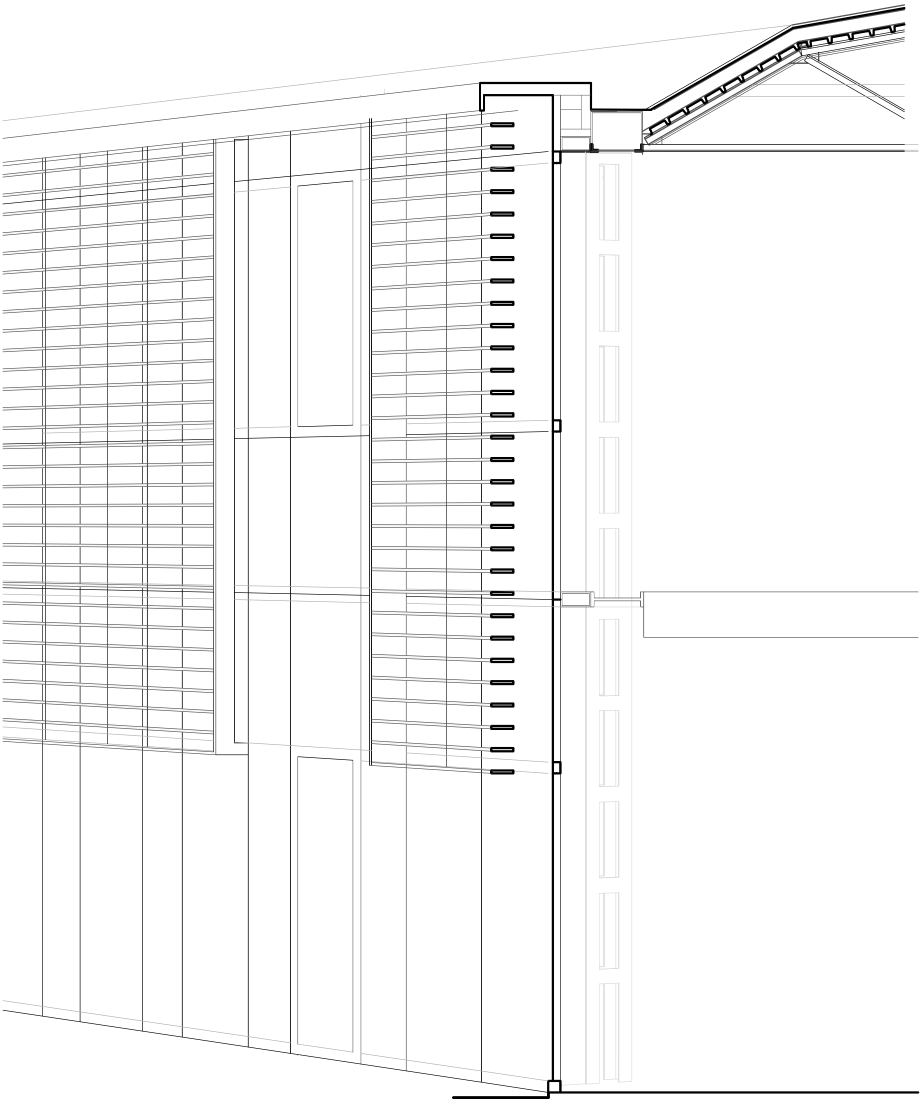


c2. new façade: shading devices

The geometry of the building, with projections and returns, together with the size, distribution, orientation and inclination of transparent facade components are the main elements relevant for the effective intensity of solar radiation.
The interior illumination by means of daylight, the heat load due to solar gains and the visual contact with the outside world are also affected by the arrangement and the properties of the glazing and the additional components for shading, controlling glass and redirecting daylight.

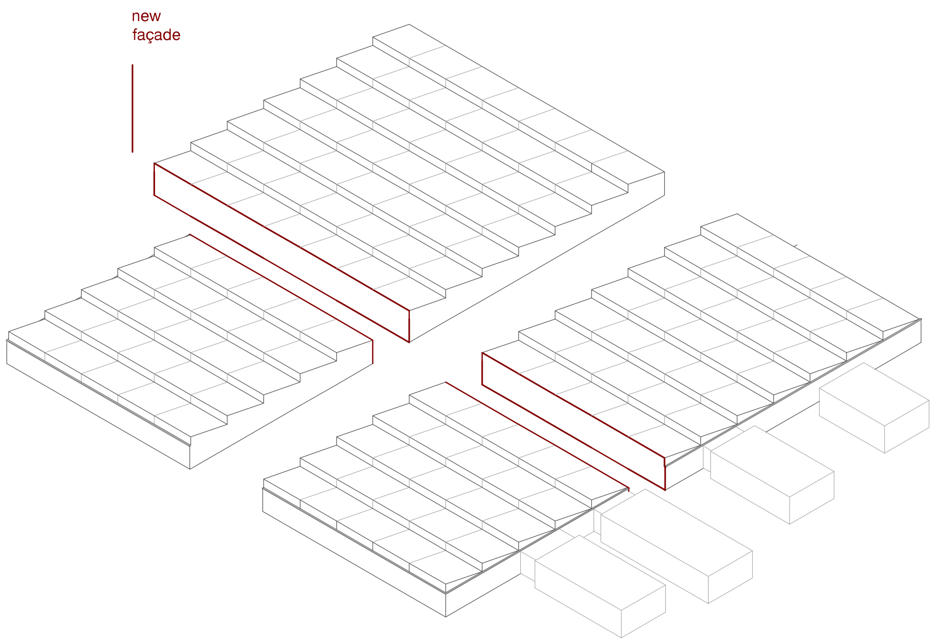


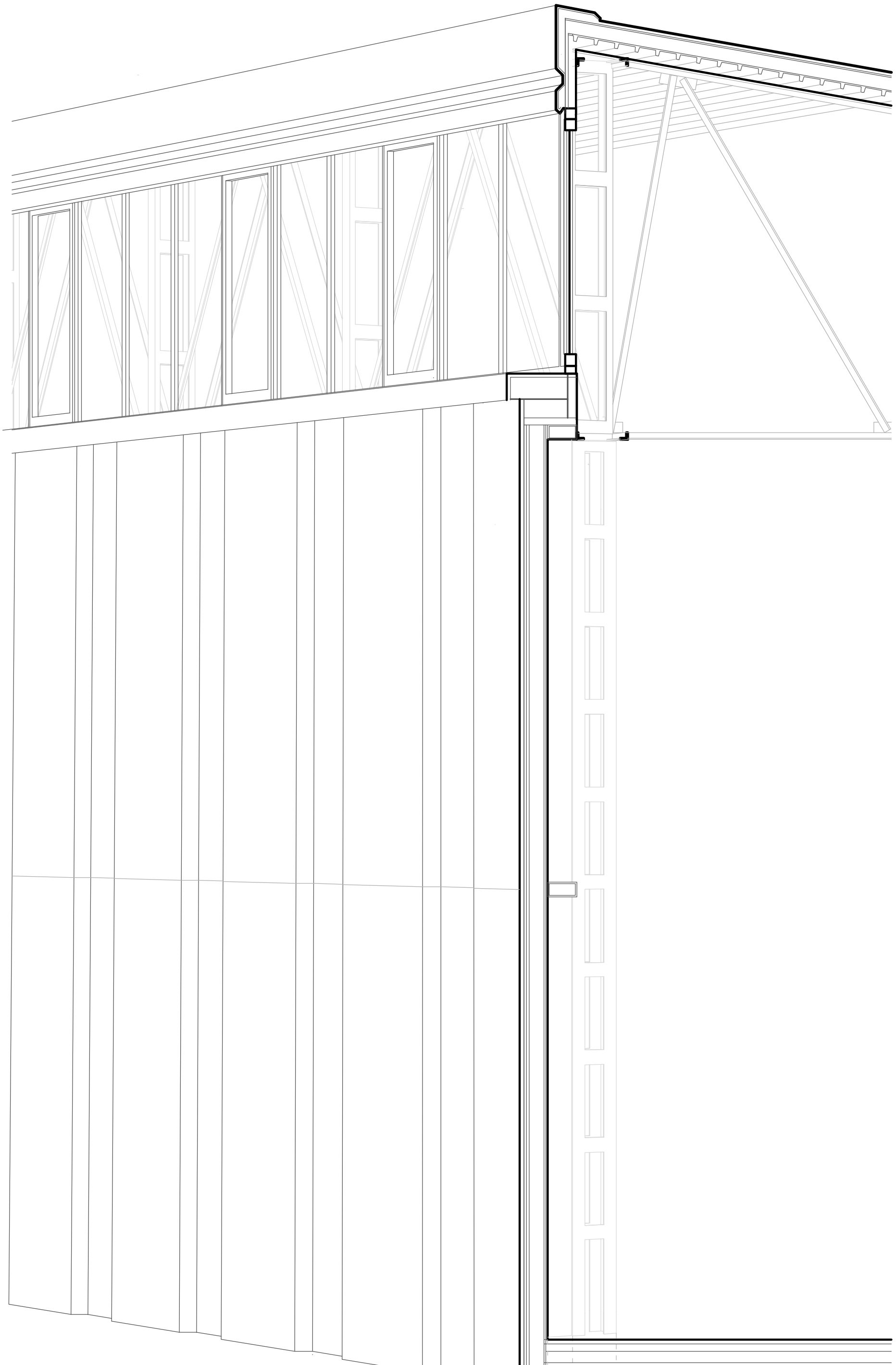


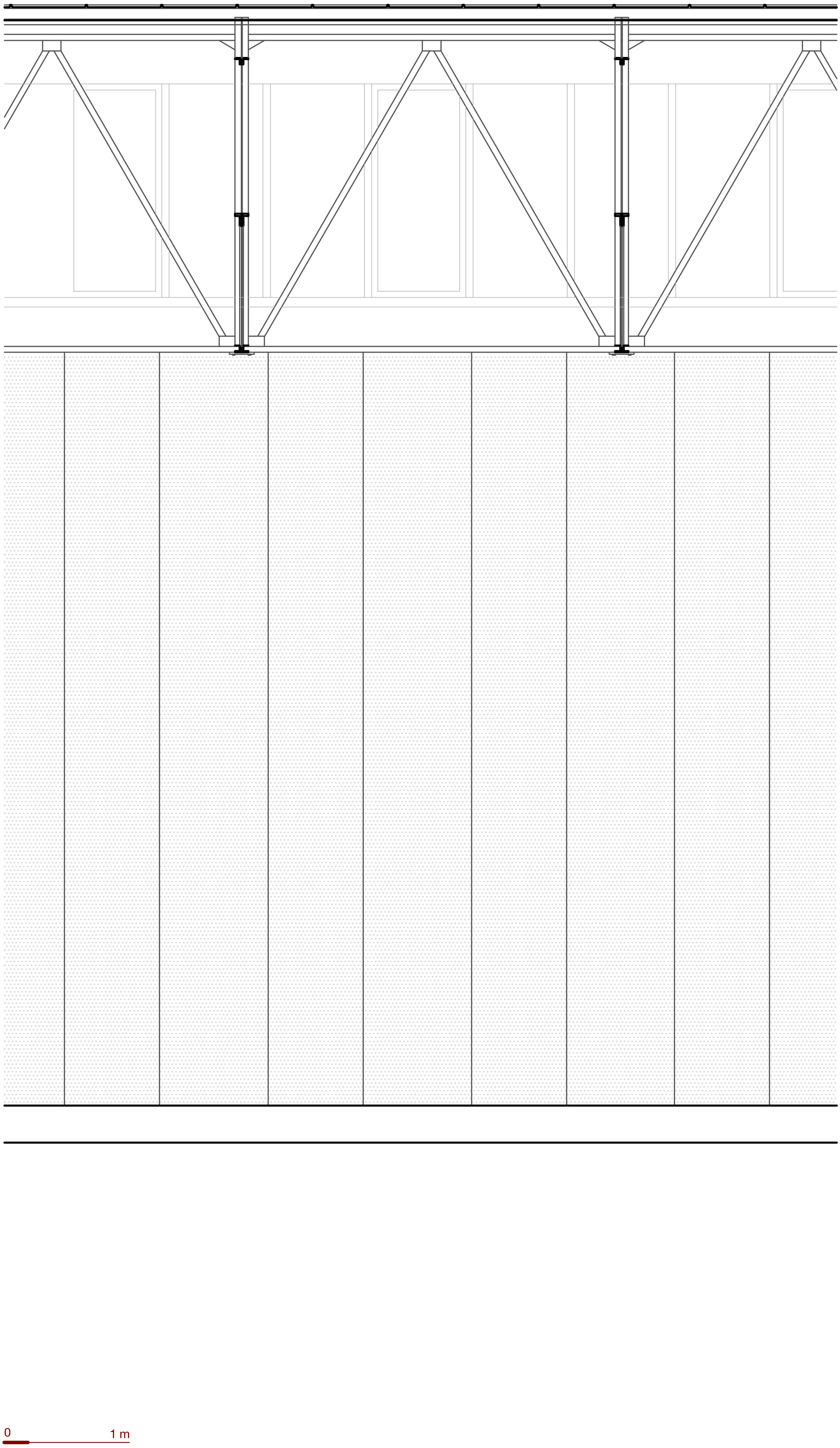


d. new façade: opaque elements

The opaque elements to create the new parts of the building envelope would respect the original modular and geometrical features of the façade. The opaque component is thus proposed in two measures which would be assembled alternating, as the original precast concrete panels.



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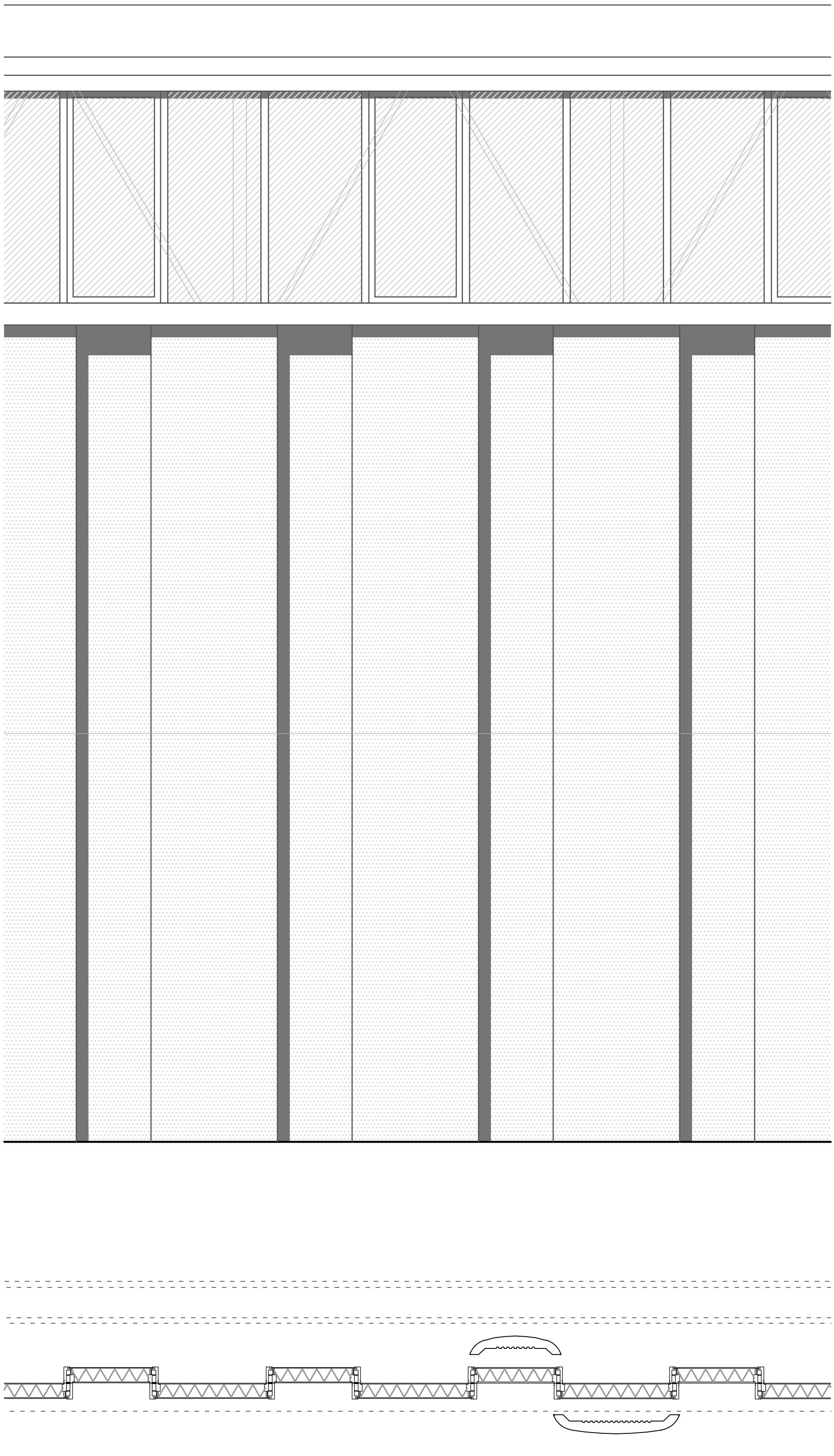
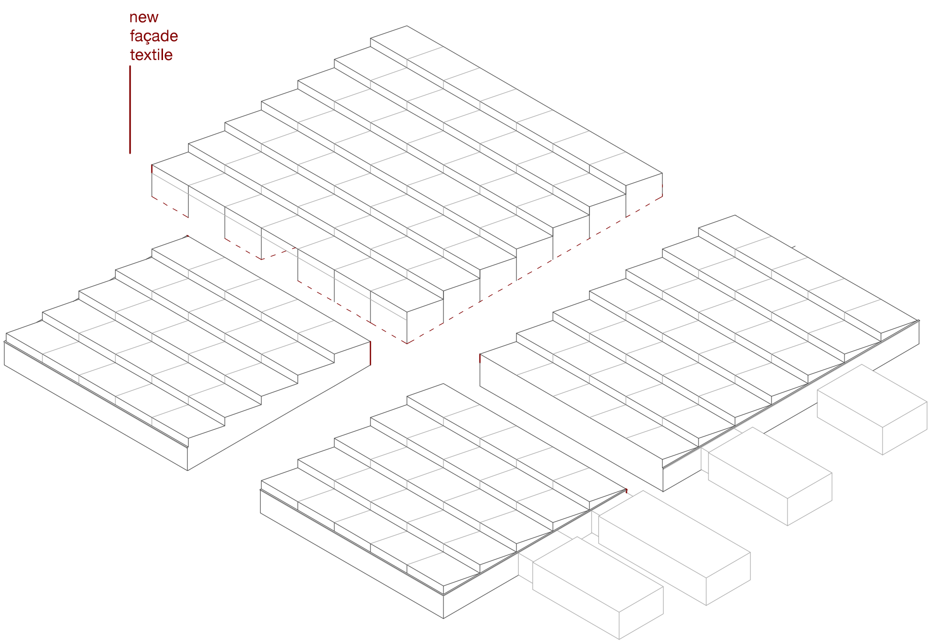
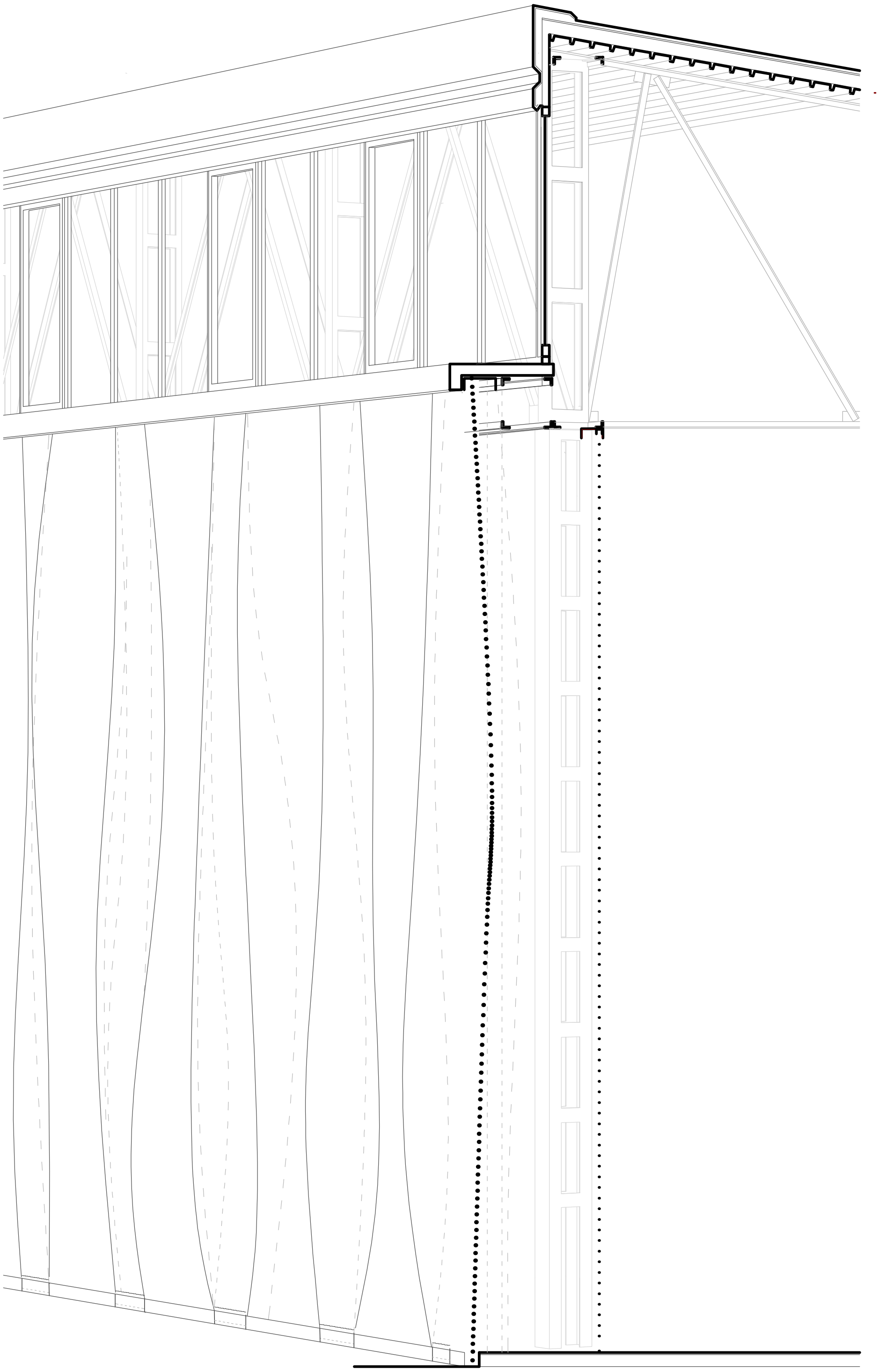


e. new façade: textile elements

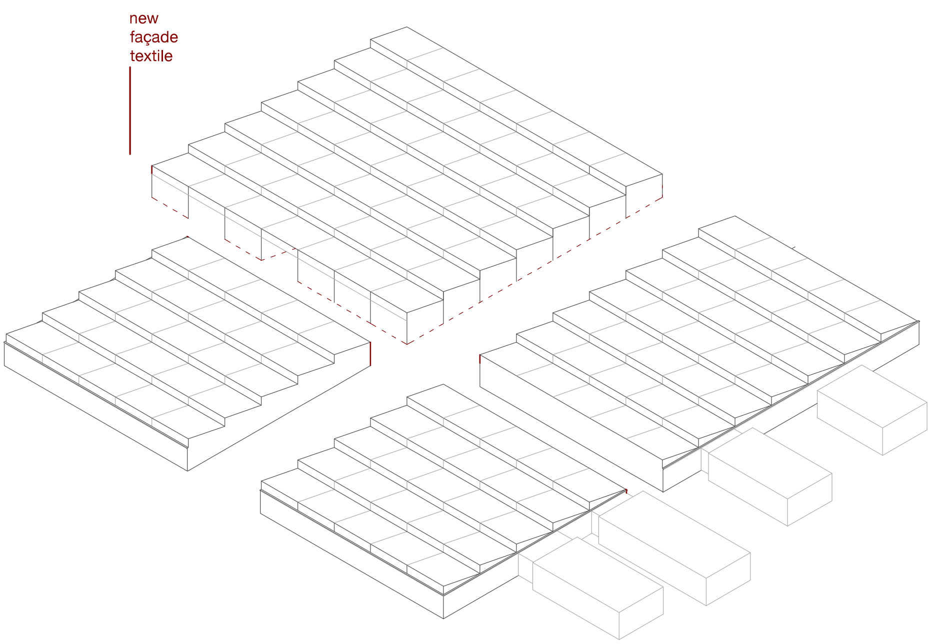
External textile façade elements would be a particularly suited solution for giving protection and shade to some parts of the building and adapting to temporary uses of its spaces.

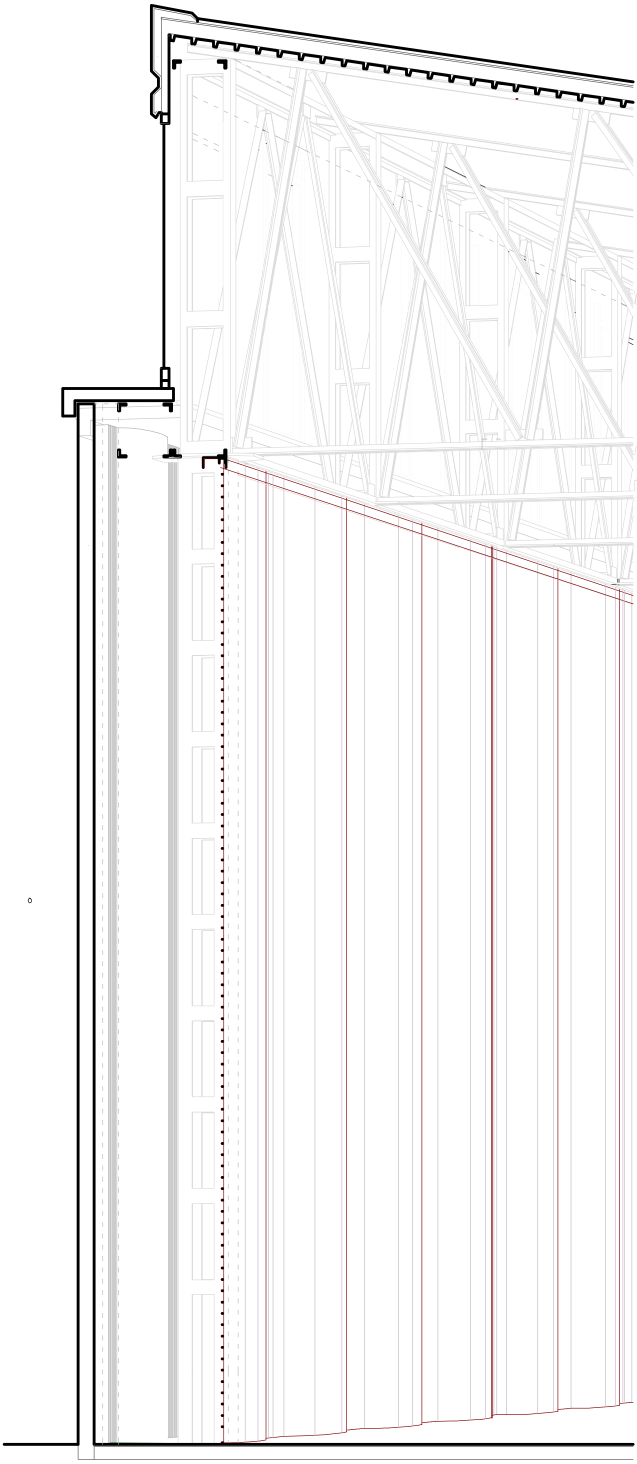
Vertical awning in a variety of material constitute a lateral closing allowing to excellent protection from wind and rainwater, being now available with shading, dimming, transparent, or waterproof fabrics.
On the other hand, mesh curtain systems, characterised by various materials, mesh types, spacing, colours and inclinations, might be used to reduce the entrance of sunlight while allowing vision and ventilation.





Textile elements are ideal for space divider applications too and, given their sound-absorbent properties, were often adopted to improve the acoustic of the rooms.
Additionally, the interior effect of the original façade - made with curved precast concrete panels alternating, which suggested a textile nature of the building skin - would be recreated through internal curtains which would also conceal the retrofit work.





existing windows,
oriented north-east,
providing ambient and
task lighting

internal drapery,
evocatin the original
façade design

F. 3-32: Zollverein School of Management and Design, Essen, DE, 2005, SANAA (www.arcspace.com)

F. 3-33: DI_Telegraph, former Central Telegraph, Moscow, RU, renovation 2014, Archiproba studios (www.archiproba.com)

CONCLUSIONS

The evolution of precast concrete for industrial buildings in Italy, considering their prevalence, features and current condition, as discussed in the first chapter, has pointed out the relevance of the development of prefabricated system and precast concrete panels through history, architecture and design and has resulted in the creation of a database for the documentation of the use of concrete and especially precast concrete panels in the industrial architecture of the late twentieth century in Italy. On the one hand, the discussion of the main aspects of the evolution of the industrial building type, according to the technological progresses and especially with the implementation of precast concrete, has pointed out the remarkable presence of prefabricated industrial building in Italy.

Industrial architecture in Italy has, in fact, largely concentrated upon concrete construction techniques and, between the ‘50s and the ‘70s, many Italian designers experimented with the use of precast concrete elements in industrial construction: several of them took the opportunity to introduce new technologies and brand-images by designing their own precast concrete elements, while others exploited the possibilities presented by prefabrication and standardisation to inject their personal modernist language into industrial architecture.

Research into the issue has produced the catalogue of “Concrete industrial architecture in Italy: 1950-1980”, which lists notable buildings constructed using both cast-in-place and pre-cast concrete methods, as well as architects and companies operating in the field. The catalogue is a ‘open’ tool and also proposes possible future implementations. Additionally, the catologuing system is able to track the use and condition of buildings over time by recording and updating information on the current activity taking place in the facility and monitoring their state and any possible damage.

In the second chapter the issues related to protection and preservation, performance degradation and upgrade, and adaptive reuse of industrial architecture have been discussed in detail.

The discussion on prefabricated industrial architecture also underlined a consideration of the meanings and values of these pieces of ‘contemporary industrial archaeology’ and their protection. Although these constructions constitutes a building stock characterised by seriality and uniformity, sometimes even works of particular architectural value have emerged, as significant examples of a flourishing historical and cultural situation, technological development, or theoretical research and design practice of notable authors. Even though the recognition of these values of industrial architecture has reached full maturity in recent years, especially with the initiatives for

documentation and valorisation of twentieth century architecture, the issues of protection and conservation - recommendation for intervention - appear to be part of an investigation still open in Italy. The different degrees of protection provided by the Italian regulatory framework show, in fact, different possibilities, involving national and/or local and municipal authorities and various legal measures and planning instruments - as verified in the regional area of Friuli Venezia Giulia. In addition, specific problems have arisen regarding the preservation of twentieth century architecture, with respect to which the current regulations reveals several critical points (age limit, effectiveness of protection measures).
The specific issues of performance degradation of industrial building have been discussed as related to the current state of knowledge and the identification of the specific vulnerabilities of prefabricated building and precast concrete elements. The seismic vulnerability, highlighted also by the recent earthquakes in the country, was confirmed as one of most relevant issue regarding prefabricated industrial building, being related to the very nature of this building type - and in fact the difficulties in fulfilling safety requirements depend also on precast concrete panels, even if non-structural elements.
On the other hand, the problem of the material decay and weathering and therefore the issues of concrete deterioration, however widely investigated in literature, has been discussed referring to the growing awareness and concern about possible intervention approaches for fair-face concrete and special components such as precast concrete panels.
The performance of the building envelope was and will continue to be of major concern, as industrial buildings are often characterised by their inability to fulfil current requirements for energy efficiency and sustainability. The problem of thermal performance - as highlighted by many studies and discussed in detail for a case study in the regional area of Friuli Venezia Giulia -, resulted particularly relevant as largely dependent on the precast concrete walls.
However, besides the performance degradation, the growing concern about sustainability has put in question also other issues for possible further development of the study, such as the end of life disposal, particularly of under-utilised or abandoned industrial buildings.
The discussion of the possibilities for reuse and renovation, physical and functional, of production facilities has highlighted some main topics of the current approach for the transformation of industrial assets: the aspects of sustainability, the principles and criteria for adaptive reuse, the new uses and new forms of work, the design concepts applied in the reuse of industrial buildings, especially regarding the adaptations and renovation of the building envelope.

This reference framework for large and small scale interventions on industrial assets and the considerations on functional adaptation, quality upgrade and aesthetic renovation have been implemented for the typological transformation of a piece of industrial architecture through the redesign of the panels in the third chapter.

The Sèleco plant, built in the late ‘60s and designed by the architect Gino Valle for the company Zanussi, resulted in fact a case in point in the past and present scenario of prefabricated architecture for the industry. Moreover, as was often the case for big Italian companies, the evolution of Zanussi Industries proved to be accompanied by the proliferation of new and up-to-date workplaces and production facilities, and for instance the successful cooperation with the architect Gino Valle led to interesting outcomes in industrial buildings - like the Sèleco plant - which now deserve protection and valorisation.
From the analysis of the Sèleco building, according to the original project, significant details have emerged, ranging from its original organisation to its constructional and technological features and the special design of the façade made with the peculiar precast concrete panels.
Following a brief discussion of the solutions for converting the facility, the Sèleco building proved to be suited to many possible uses but in need of adequate solutions for its adaptation in order to serve the new uses as well as the current requirements. The general architectural adaptations - envisaged to illustrate the scenario of possible transformations of the site - pointed out how the building’s existing façade would need to be adapted and the provision of new parts of building envelope would be required. Thus the study has proposed solutions for energy retrofit, additions and replacements - ranging from transparent to opaque and textile elements for the new façade - to be understood as a set of technological solutions and components to be used for creating this new cladding respecting the original formal and architectural values of the building.

The study, in these three chapters, lead from a general and theoretical overview of the subject to the discussion of specific and concrete cases, with the aim of increasing the debate around the issue, raising awareness about the challenges and opportunities offered by this architectural heritage and suggesting a range of possible interventions and strategies for its renovation. The research outcomes will hopufully encourage the revaluation and the renovation of this building heritage which, being an important trace of the (industrial) development of the country in the recent past, would become one of the incentives to favor a new cycle in the near future.

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www.breuer.syr.edu - Marcel Breuer digital archive
domus.immanens.com/ - Domus journal digital archive
www.archivio.unita.it - L'Unità newspaper Archive
www.aap.beniculturali.it - DGAAP Italian body for contemporary architecture
architetturecontemporanee.beniculturali.it - National census of architecture of the late twentieth century
www.iccd.beniculturali.it - ICCD Central Institute for Cataloguing and Documentation -
www.docomomo.com - Docomomo International
www.docomomoitalia.it - Docomomo Italy
www.exhibition.docomomo.com - Docomomo International Register
www.arquitecturaeindustria.org - Docomomo iberico register for industrial architecture
www.tulliaiori.com/SIXXI/ - Twentieth Century Structural Engineering: The Italian Contribution
atlante.iuav.it - Atlas of Italian architecture of the '50s and' '60s: figures, forms, construction techniques
www.architetturadelmoderno.it - ITER project on modern architecture in Italy
www.fondazionefavini.it - Fondazione Aldo Favini
www.formsandstructures.polimi.it - Forms and Structures catalogue
recycleitaly.iuav.it - National research project RECYCLE ITALY

historicengland.org.uk - Historic England
www.english-heritage.org.uk - English Heritage
vincoliinrete.beniculturali.it - Italian catalogue of protected cultural assets
www.lombardiabeniculturali.it - Catalogue of cultural heritage, Lombardia region
www.ipac.regione.fvg.it - Catalogue of cultural heritage, Friuli Venezia Giulia region
www.patrimonioindustriale.it - AIPAI Italian Association for the Industrial Heritage
www.st-al.com - STILL ALIVE project on industrial ruins photography
www.saveindustrialheritage.org -
www.urban-reuse.eu - Catalogue of reuse project by Politecnico di Torino
www.gizmoweb.org - portal for architectural research

Concrete associations
www.concrete.org.uk - The Concrete Society
www.concretecentre.com - Concrete Quarterly Archive
www.concrete.org - ACI American Concrete Institute
www.fib-international.org - FIB the International Federation for Structural Concrete
www.aitecweb.com - AITEC Italian Cement Association
www.assobeton.it - ASSOBETON Italian association precast concrete
www.bibm.eu.- BIBM - European Federation for Precast Concrete
www.italcementi.it - ITALCEMENTI Group
www.apti.org - APTI Association for Preservation Technology International

History of construction companies
www.storiaindustria.it - STORIAINDUSTRIA Online center for industrial culture
www.museimpresa.com - MUSEIMPRESA Italian association of company museums and archives
www.imprese.san.beniculturali.it - SAN Italian National archival system - companies

www.altan.com - ALTAN Prefabbricati S.p.A
www.emeursella.it - E.M.E. URSELLA S.p.A.
www.cantirs.it - *CANTIRS Museo del patrimonio edile* of the Udine province
www.seleco.tv - SELECO company
www.super-fluo.com - Super\\Fluo company
www.zml.it - ZML industries S.p.A.
www.zanussiprofessional.it - Zanussi Electrolux Group
www.benetton.it - Benetton company

Regulation and energy efficiency
www.itaca.org - ITACA Protocol
www.isbeitalia.org - IiSBE International Initiative for a Sustainable Built Environment
www.regione.fvg.it - Friuli Venezia Giulia Region
www.comune.pordenone.it - Pordenone town

Projects and architectural fims
www.landschaftspark.de - Landschaftspark Duisburg-Nord
www.oberhausen.de - Oberhausen gasometer
www.nino-hochbau.de - Nino Hochbau centre
www.communaute-urbaine-dunkerque.fr - Dunkirk municipality
www.la-fonderie.fr - Campus La Fonderie in Mulhouse, FR
www.mongiello-plisson.com - Mongiello & Plisson architect
www.lacatonvassal.com - Lacaton & Vassal architect
www.claudionardi.it - Claudio Nardi architect
www.isolarchitetti.it - Isolarchitetti architects
www.cbarchitekten.com - Clemens Bachmann Architekten
www.langarita-navarro.com - Langarita-Navarro Arquitectos www.vulcanicaarchitettura.com - VulcanicaArchitettura architects
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www.woodsbagot.com - Woods Bagot & Tridente Architects
www.diverserighestudio.it - Diverserighe studio architectural firm
www.cittaarchitettura.it - Andrea Oliva architect
www.studiomangiarotti.com - Mangiarotti architects
www.architettivalle.net - Valle Architetti Associati architectural firm
www.archiproba.com - Archiproba studios
www.divisare.com - portal for architecture
www.arcspace.com - portal for architecture
www.archdaily.com - portal for architecture
www.detail-online.com - portal for architecture

ABBREVIATIONS

	Province		Province
AL	Alessandria	MO	Modena
AN	Ancona	MS	Massa-Carrara
AO	Aosta	MT	Matera
AQ	L'Aquila	NA	Napoli
AR	Arezzo	NO	Novara
AT	Asti	PA	Palermo
BA	Bari	PC	Piacenza
BG	Bergamo	PD	Padova
BI	Biella	PE	Pescara
BL	Belluno	PG	Perugia
BN	Benevento	PI	Pisa
BO	Bologna	PN	Pordenone
BR	Brindisi	PR	Parma
BS	Brescia	PT	Pistoia
BZ	Bolzano	PV	Pavia
CA	Cagliari	PZ	Potenza
CE	Caserta	RA	Ravenna
CH	Chieti	RC	Reggio di Calabria
CN	Cuneo	RE	Reggio nell'Emilia
CO	Como	RI	Rieti
CR	Cremona	RM	Roma
CS	Cosenza	RN	Rimini
CT	Catania	RO	Rovigo
FE	Ferrara	SA	Salerno
FI	Firenze	SI	Siena
GE	Genova	SO	Sondrio
GO	Gorizia	SP	La Spezia
GR	Grosseto	SV	Savona
IM	Imperia	TA	Taranto
KR	Crotone	TN	Trento
LC	Lecco	TO	Torino
LE	Lecce	TR	Terni
LI	Livorno	TS	Trieste
LO	Lodi	TV	Treviso
LT	Latina	UD	Udine
LU	Lucca	VA	Varese
MC	Macerata	VC	Vercelli
ME	Messina	VE	Venezia
MI	Milano	VI	Vicenza
MN	Mantova	VR	Verona

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