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Industrial form in prestressed concrete. An historical inquiry about the structural design of Aldo Favini and Angelo Mangiarotti (1950-1980)

La forma industrial del hormigón pretensado. Una investigación histórica sobre el diseño estructural de Aldo Favini y Angelo Mangiarotti (1950-1980)

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ABSTRACT

In June 1966 the little «Parrish Church of Baranzate», designed by Angelo Mangiarotti with Aldo Favini and built on the outskirts of Milan, was published in «Informes de la Construcción». Its «brillant structure» made up by precast, prestressed concrete elements, bear witness to a structural architecture that arose in Northern Italy in the aftermath of the Second World War, deeply intertwined with the building industry sector's and industrial design's ample development.

With reinforced concrete as the reference point, the structural topic of the medium-length span – especially to face the fast reconstruction of non housing buildings – engaged a generation of structural engineers in the design of precast elements. From 50's to 70's, thin shell, slabs and beams, shaped by the "logic of form" or "strengthened" by prestression, dealt in finding the ideal shape (in both structural and architectural terms) to the "handmade" dimension of Italian industrialization.

Keywords: structural design; 20th Century; prestressed concrete; industrialized construction; Italy; Spain, SIXXI research project.

RESUMEN

En junio de 1966, la «Iglesia Parroquial de Baranzate», diseñada por Angelo Mangiarotti en colaboratión con Aldo Favini y construida en los alrededores de Milán, se publicó en «Informes de la Construcción»: la «brillante estructura» del edificio, que está compuesta por elementos prefabricados de hormigón pretensado, es testigo de una arquitectura estructural que se formó, a lo largo de la Postguerra en el norte de Italia, en sinergia con el desarrollo de la industria y del diseño industrial.

En el horizonte común del hormigón armado, plasmado y adiestrado por la resistencia en forma y pretensado, la estructura de luz intermedio – con respecto a la rápida reconstrucción de la edificación no residencial – vuelve a diseñarse a través de elementos prefabricados: entre los años '50 y '70, bovedas, losas, vigas se modelan en la búsqueda de la forma (estructural y arquitectónica) ideal para la dimensión «artesanal» de la industrialización italiana.

Palabras clave: *diseño estructural; siglo xx; hormigón pretensado; construcción industrializada; Italia; España, SIXXI proyecto de investigación.*

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1. THE SWISS EXILE IN WAR TIME: A COMMON GROUND

Immediately after the Armistice between Italy and the Allies in 1943, Northern Italy was occupied by German troops. More than 20,000 Italians, many of them university students, fled to Switzerland to avoid being conscripted into the Italian Social Republican army or taken to the new forced labor camps in Germany.

University internment camps were set up in schools of Lausanne, Geneva, Friborg and Neuchatel, which enabled the students to continue their studies between 1944 and 1945. Instruction in engineering was organized in the respective faculties of Lausanne University; Gustavo Colonetti was the dean in charge of courses that were taught by both Italian and Swiss professors, with the assistance of young engineers and architect, enrolled at the university as postgraduate students.

A class of architects, designers and engineers came together, within the Lausanne institute, with common themes in their studies and practice experimentations; the prestressing of reinforced concrete, new methods for calculating thin vaults and shells, advanced construction techniques and the industrialization of the building process became familiar topics of discussion amongst the young designers in exile[1].

Get back to Italy the Lausanne students settled mainly in Lombardy, where they continued to work together, starting up their own professional businesses and forming partnerships and associations. Here, the post-war Reconstruction, with American assistance, was driven by industry. While new factories arose all over the region, a settlement between industrialization and the building sector was pioneering established.

According to this - beyond the large reconstruction projects of roads and railways (as the foremost fieldwork of the Italian School of engineering) and the emergency of the housing sector's rebuilding (as the main focus of the post-war architectural debate) - a new typology of structure came on the boards of the structural project: the resolution of the medium-sized span (around 20 to 30 metres) of the factory building.

With the aim to industrialize the building process and reinforced concrete imposed by economic-productive system, pre-compression emerged as foremost tool of the structural practice: reinforced concrete's structural elements, "strengthened" by prestression, were thinner and lighter, more advantageous than steel and therefore able to be prefabricated (1).

2. FAVINI'S FIRST EXPERIMENTALISM

Aldo Favini, who taught in Colonetti's course on reinforced concrete in Lausanne, considered using pre-compression in medium-sized structures, as he settled in Milan.

Facing the Reconstruction, he aimed to develop a cost effective roofing system that could be easily adapted to industrial building.

Basing on the research that he had started in Switzerland (2), he focused his work on thin concrete shell that he aimed to enhance with the introduction of a post-tension system.

This pragmatic purpose disclosed a new operative perspective and needed new technical instruments.

Imagining a thin shell, most commonly-used devices for anchoring and tending cables were too bulky to be inserted in the tiny thickness of concrete. (The most common device, the Fressynet[2] anchorage, was designed to lock 12 cables, and when it was tested with only 6 cables it failed in resistance[3]).

So, after a brief visit to the Fressynet laboratory in Lausanne, Favini started to develop a series of prototypes for testing and stressing a new, smaller anchorage. With the help of a mechanic's workshop settled in Varallo Pombia (his home town), he finally achieved his goal: after months of work - on 18 December 1951 – he filed a patent for his new "6-strand" post-tension anchorage system[4].

The device was considerably smaller in size than its competitors, and as it consisted of two truncated cones - one of them axially perforated for insertion of the second by "wedge forcing" - it was easy and straightforward to operate (Picture 1). Uniform tension of the strands was, furthermore, assured by the invention of a complementary hydraulic jack, patented on 27 July 1953[5].

Therefore, all the essential instruments were held by favini to apply a miniaturized post-tension technology to thin concrete shell. The opportunity came soon.

In 1954 he was involved in the structural design of the roof of the student's dining hall at Bocconi University. The roof span around 18 metres and it was the ideal object to test a post-tensioned concrete shell: 9 hollow prisms, 8 cm thick, were combined in a corrugated vault, strengthened by 9 strands.

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[1] Historical Archive of the University of Milan, APICE Documentation Centre, Milan, «Italian University in Switzerland Found (1943-1945)».

[2] Central State Archive, Rome, Patent Fund, Fressynet, E., patent n. 419867, «Dispositivo di messa in tensione e di ancoraggio di cavi adatti in particolare per l'esecuzione di costruzioni in calcestruzzo preventivamente costretto» [Fixing and cable anchoring device particularly suited for the execution of precast concrete constructions], 7th August 1941.

[3] Historical Archives of the Politecnico of Milan, Aldo Favini Fund, CNR, «Centro di Studio sugli Stati di Coazione Elastica» [Study Center for Elastic co-action in reinforced concrete], «Prove diverse su ancoraggi per fili di 5 mm di diametro con morsa in ghisa per 12 fili, committente: ing. Aldo Favini a Milano» [Tests on wire anchors of 5 mm diameter with cast iron vice for 12 threads. ing. Aldo Favini in Milan], 10th August 1950.

[4] Central State Archive, Rome, Patent Fund, Favini, A., patent n. 4822696, «Dispositivo per ancorare una serie di 3 o più fili o tondini metallici, particolarmente per l'applicazione del cemento armato precompresso» [Anchoring device for 3 or 6 cables particularly suited for the execution of precast concrete constructions], 18 dicembre 1951.

[5] Central State Archive, Rome, Patent Fund, Favini, A., patent n. 503538, «Dispositivo per tendere in modo uguale una serie di tre o più fili o tondini metallici, particolarmente per tendere fili o tondini costituenti armatura di strutture in cemento armato precompresso» [Tensioning device particularly suited for the execution of precast concrete constructions], 27 luglio 1953.

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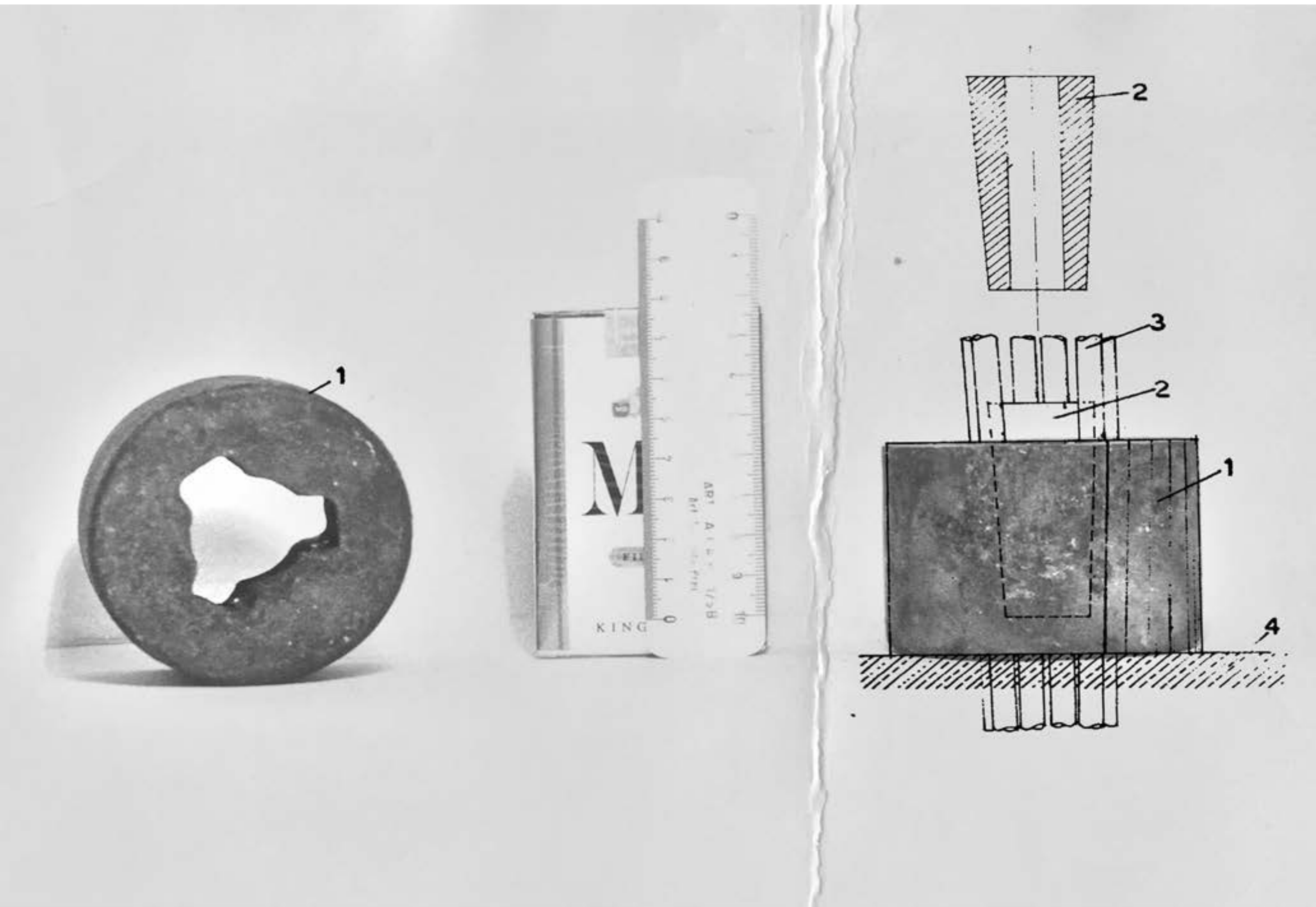


Picture 1. Favini system of pre-compression, Anchorage device, 1953 (Historical Archive of Milan Politecnico, Aldo Favini Found, Rome)

Because of the new anchorages, smaller in size, the steel cable system remained completely hidden by the tiny concrete section, without altering the geometric structure and structural aesthetic of the thin shell.

In spite of the excellent results in saving on materials, the Bocconi roof was however still uneconomical: the continuous post-tensioned vault, optimal in structural terms, required the construction of a complex and expensive timber rib for the cast in place.

To comply this structural figure at the fast, cost-effective construction of industrial buildings, the construction process had to be reinvented.

The occasion came up only a few months later, with the project for the "Ernesto Silvestri Mechanical Workshop" in Dormelletto. A small plant of just 750m² was required, but with interesting 20-metre spans: the befitting building to a prototype (3).

So, the thin continuous shell was divided into 5 elements: 5 adjacent circular thin vaults – with their generatrices facing the smaller side of the building – disposed as sheds and only 10 cm thick.

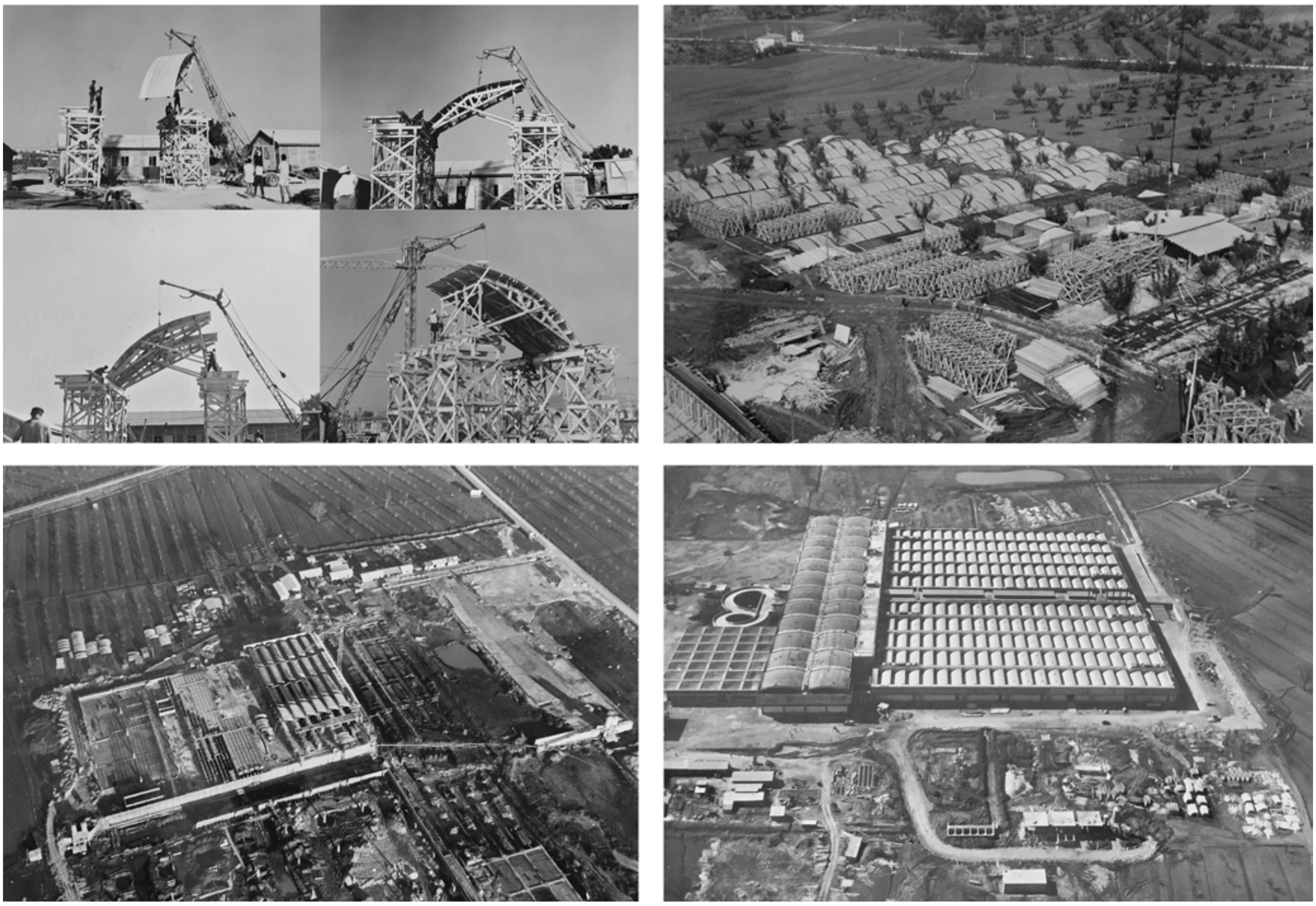
Each vault was strengthened by post-tension: 5 cables and their anchors were embedded in the casting and the system disappeared deceptively into the concrete sections.

Even more suitable for the overhead lighting required in industrial spaces, the discretization of the vault into separate elements introduced a ground-breaking construction process: with the idea to precast on-site the temporary structures, the timber scaffolding and rib that would have to be mounted as a all to support the casting of the entire vault, was split into a number of modules, less than one meter in width, portable and reusable.

Castings could thus be laid over the set-up of the temporary structures, conveniently reducing the construction time; while the first shell was being cast (the rib for which counts 21 modules), the sections of rib required for the second could be put in place. The sections for the two ribs could then be reused in stages to construct the successive spans for the vault, with considerable savings in terms of timber, labor and costs.

The original construction system, prototyped in dormelletto, underwent extensive testing between 1958 and 1963 with the construction of the enormous perugina warehouse in perugia, designed with the engineering carlo rusconi clerici[6]. For

[6] Favini and Rusconi Clerici met first in the framework of Lausanne University during the exile. As primary source, see Historical Archive of the University of Milan, APICE Documentation Centre, Milan, «Italian University in Switzerland Found (1943-1945)».



Picture 2. Favini's post-tensioned concrete thin shell construction system, Perugina plant in Perugia, 1963 (Central State Historical Archive, Sogene Found, Rome)

this building, which comprised 210 thin vaults of the same type, the construction site was divided in two separate fields: a castings in-situ field (where the construction of the pillars was started) and a carpentry workshop to prefabricate scaffolding and ribs. (Picture 2)

So, with the work of just two men (a carpenter and a carpenter's mate), 273 modules of ribs were constructed in just over a month. The modules covered the extension of 30 vaults, which formed one of the 7 segments into which the building was divided: by overlapping the cast in-situ of the pillars to the scalar reuse of the unit of the ribs the entire roof extension was completed in only five month[7].

Whilst using this standardized construction method, the thin-vault cast entirely in-situ was extremely versatile in terms of its size, as it could also be adapted for similar structural elements with unusual spans. In 1963, for example, this strong, economical type of post-tensioned structure was used for the outstanding span of 31 metres, with the same tiny thickness (4).

3. THE COMMON WOK OF FAVINI AND MANGIAROTTI

Between 1956 and 1962, Favini worked regularly with Angelo Mangiarotti (5), who he did met first at University of Lausanne. In 1956, Mangiarotti, in conjunction with Bruno Morassutti, was appointed to design the new church in Baranzate; this was part of a wider reconstruction plan of churches on the outskirts of Milan, so it had to be a prototype for a series of similar buildings.

For Mangiarotti, this was the ideal spot to apply the principles of rationalization and industrialisation that he had learned in switzerland. In the actual framework of reinforced concrete construction, prestressing was still the much suitable tool to allowed mid-span structures, reduced in weight and thickness, to be designed economically, also as precast elements.

The construction technique, in the thought of the designers, was "not about translating a problem of expression, but it is a medium of inspiration" (6). The special conception and the structure emerged simultaneously. Placing an imposing slab on four slender pillars spaced so that the absolute value of the bending moment at the center was equal to that at the supports, a rectangular hall with a narrow border of glass was created.

The slab was composed of three types of element that differed in terms of their structural role and in the way they were fabricated: two slot-in reinforced transverse beams cast in situ, six X-shaped longitudinal beams created from a series of precast segments for on-site assembly, and 150 prefabricated

[7] Central State Archive, Rome, Società Generale Immobiliare Found, Contracts and Payments (1955-1976), b. 72, Perugina Plant, 1961, Contracts.

Picture 3. Favini and Mangiarotti, Church of Baranzate, 2014 (photography by Sergio Poretti, SIXXI Archive, University of Rome "Tor Vergata")

hollow corrugated roof sections to be laid side by side on the longitudinal beams.

The structural design of the slab was created using a practical post tension technique; not just as Favini already did (addressing the technique to reduce the thickness and increase the strength of the elements) but a new practical method that rationalized the construction site.

Steel cables inserted in the X beams were not designed simply to increase their strength, they also performed a fundamental role in constructing the beams. The beams were difficult to produce as single elements, and were composed of 30 identical modules to be assembled on site. Each segment had 4 pieces, the position of two of which varied according to their sequence on the longitudinal axis of the beam, the sinuous curve that 8 harmonic steel cables must follow in order to achieve the traditional tensile stress and establish solidity of the structure.

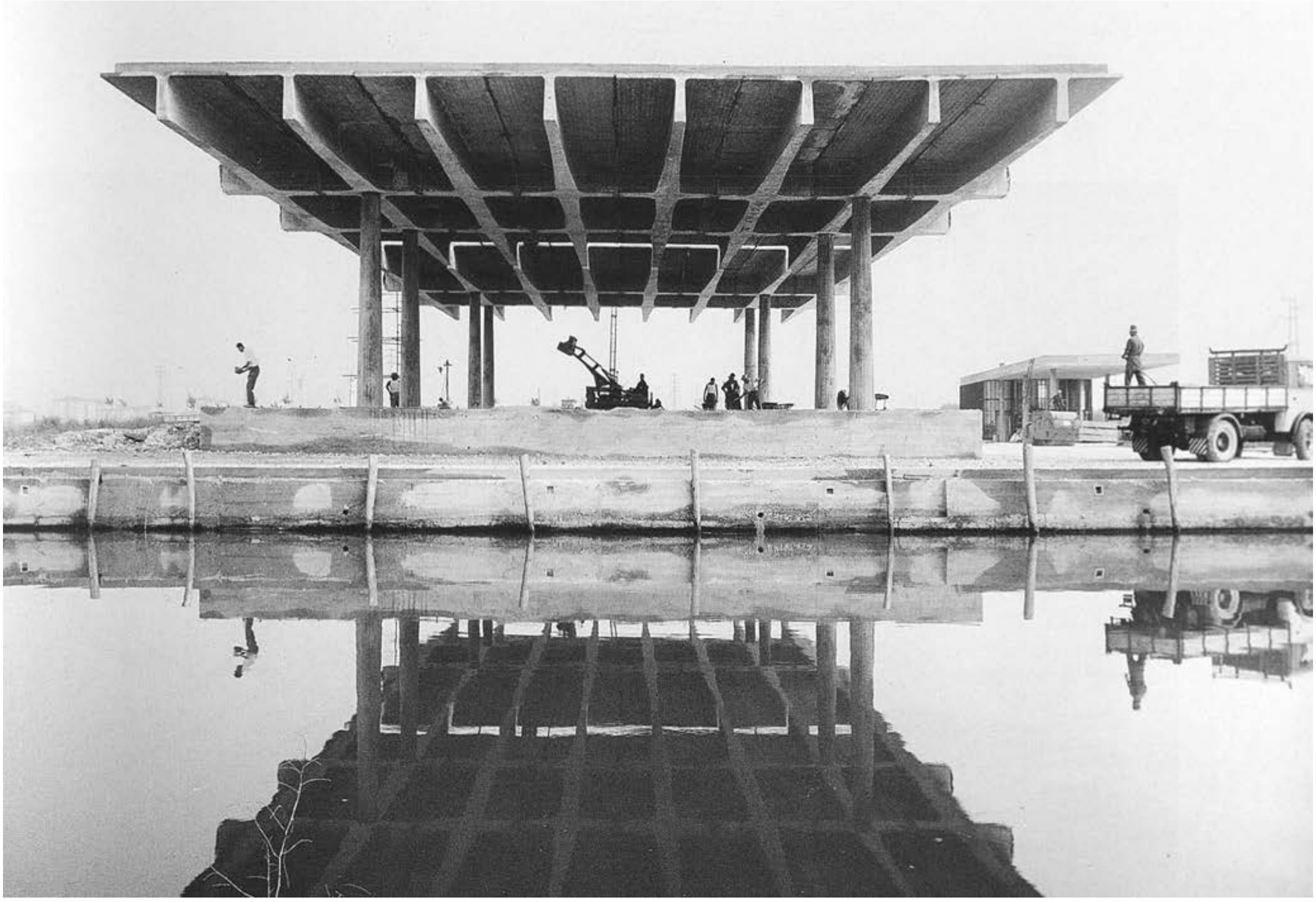
Thus devised, the segments were prefabricated in a workshop a few kilometers from the construction site, and transported to Baranzate in June 1958 together with the 150 roof sections, strung on the cables like a pearl necklace and suspended from special «telescopic beams»[8]. They were fixed to each other first with a casting of cement mortar, and when the casting of the upper structures was complete, tightened by stretching and clamping the cables.

Finally, after the structure was sealed, special X-shaped plugs were mounted along the section. With the anchorage also hidden, the prestressing system of the construction - its defining element - disappeared in the deceptive conception of the corrugated slab. (Picture 3)

In 1960, after the Baranzate church was completed, Mangiarotti and Favini were then charged with the monumental Birra Poretti warehouse project in Mestre. Like the church, the structural design focused on the "table" diagram; the spatial concept of this building also lent itself to the design of a massive roof slab supported on four vertical pillars, with overhangs on all sides. (Picture 4)

Unlike Baranzate, however, where the slab comprised three distinct types of element, the slab for the Poretti warehouse was made as a single corrugated plate formed by fusing the roof sections to the beams.

[8] Central State Archive, Rome, Patent Fund, Favini, A., patent n. 527929. «*Dispositivo per collegare telescopicamente tra una, due o più travi particolarmente adatte a costituire armature provvisorie – casseforme per solai e travi a luce variabile*» [Device for telescopically connecting between one, two or more beams which are particularly suitable for forming provisional reinforcements - formwork for variable light beams], 8th June 1955. The church's construction site was at the occasion to test the «telescopic metallic beam» patented by Favini in 1955, which allows to cast variable light beams with a single extensible scaffolding.



Picture 4. Favini and Mangiarotti, Birra Poretti plant in Mestre, 1962 (Historical Archive of Milan Politecnico, Aldo Favini Found, Rome)

Composed of 4 juxtaposed independent field, each side 22 meters long, each slab was further divided into 16 smaller structural elements, to be prefabricated on the ground and assembled on site: 64 concrete slabs corrugated in two directions, strengthened by a prestressing system along the longitudinal section and re-stitched in situ by post tension cables crossing the transversal section.

Mangiarotti's photographer, Giorgio Casali, depicted the construction site while, the gigantic blocks - corrugated according the internal stresses path - were been stitched together by the post tension cables suspended on a original scaffolding system that Favini designed especially for the purpose[9].

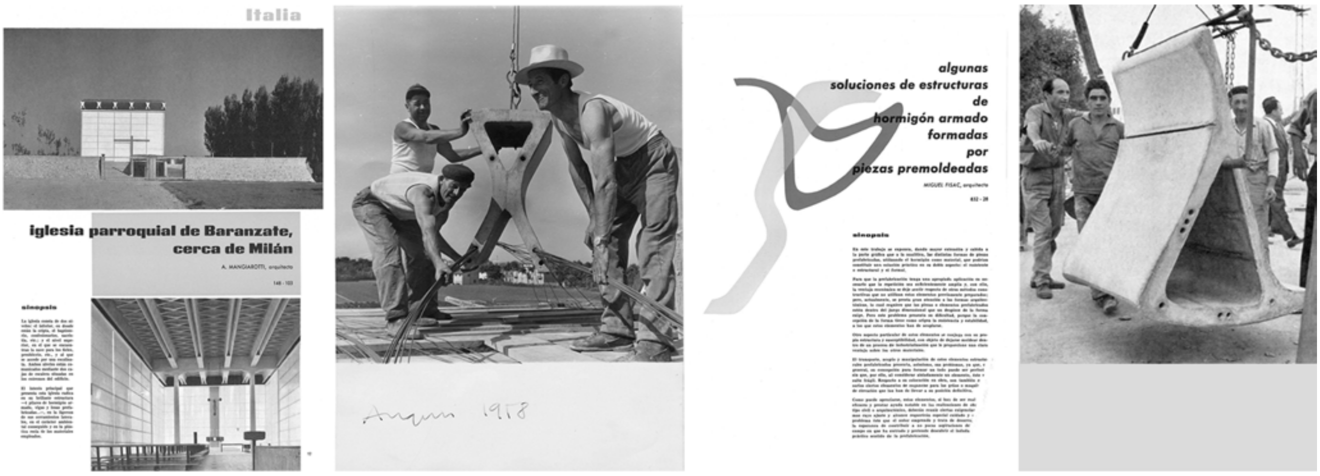
The spectacular images, together with the ones of Baranzate's structure, were quickly disseminated in both specialist engineering publications and prominent architectural journals, emerging in the international community.

Beside the Italian structural languages, globally emerged in those years in the large-scale structures framework - such as Nervi's way on large span thin-shell and Morandi cable-stayed bridges in the scientific language of prestressing (8) - Favini and Mangiarotti's structures disclosed an hybrid way of the structural design that joined the main expression of the italian school of engineering in time of its international achievement.

The realistic assumption of the new production conditions that led to the adoption of standardized elements emerged in Favini and Mangiarotti works such as a non ideological use of form resistance and prestression, that became intertwined tools of the structural practice to shape the single structural element following the stress paths or to optimize the structural diagram according to the masterful tuning of the stresses.

In this context, the church of Baranzate reached even the Spanish «hormigón pretensado» community with a documented and illustrated article published in «Informes de la Construccion» (7). The reason why the building caught the Spanish interest was its «brillant structure» which, by enclosing the architectural characters of the building, became the ideal expression of a new structural language due to the original use of prestressed reinforced concrete that mirrored the rich experimentalism on the same topic carried out in Spain in the same period and disseminated, even in Italy, through the international concrete community (9). Compared to this, Favini and Mangiarotti's structural inventions took their place in an international cluster alongside Miguel Fisac's heucos (10) (11), enabled by Carlos Barredo's miniaturization of the

[9] Central State Archive, Rome, Patent Fund, Favini, A., patent n. 720107, «*Dispositivo per il fissaggio di una estremità di un'asta trasversale a un montante per la realizzazione di ponteggi*» [Device for fastening an end of a transverse rod to an upright for making scaffolds], 11th April 1964. This patent was the last signed by Favini. In the following years he filed only "utility models".



Picture 5. Favini and Mangiarotti, Church of Baranzate published in "Infomes de la Construccion", 1, 1966; workers on the roof of the Church, 1958 (Private Archive of Alessandro Castelnuovo, Milan); Fisac's article publish on "Infomes de la Construccion", 1, 1966.

system (12), and enterprising experimentation such as Casa Barredo by Barredo and Cassinello (13). (Picture 5)

4. FAVINI'S HANDMADE SLABS, ROOFING SEGMENTS AND BEAMS

In the early 1960s industrialization of the construction process was a fundamental requirement for italian the building market. Favini, interrupted the collaboration with Mangiarotti, followed up his research on structural components for serial production, starting the idea to work on prefabricated structural elements for the fast erection of the industrial building.

In 1965, with the occasion to design «Franchi plant» in Borghesia, Favini focused on the transformation of the traditional T shape precast slab in prestressed concrete, by the design it in a new drawing: the thickness of the T-shaped transverse profile was reduced to a minimum, while the longitudinal section of the slab was redesigned following an arch segment; consequently, all connections between longitudinal and transversal sections of the element were cut on an elliptical curve.

From the combination of taut curves, a new type of precast T-shape slab was conceived: promptly called «AL.FA slab» it was sent to the Italian patent office on 26 February 1965. (Picture 6)

The request that Favini filed was unusual for an engineer: Favini claimed, indeed, for the registration of a utility model[10]. As the «AL.FA slab» did not use new state-of-the-art techniques and was only distinguished it self from similar precast structural elements by its new, thin structural profile, it was filed in this second class of patent: here, together with Italian design products, it obtained a protection on the market only dealt with its shape and drawing.

Assuming the production conditions that led the adoption of standardized elements, the «AL.FA slab» refused the anonymous design of prefabricated element and became an artifact: the choice of the shape was perfectly consistent to the structural behavior, but in an understated way, without revealing the prestressed solution that played a key role in reaching the optimal form. As an industrial product, the «AL.FA slab» was packaged in printed advertising, even before the first unit was manufactured. (Picture 7)

When the production of the «AL.FA slab» started in the Borghesia industrialization was brought into the work site and met the handmade dimension. A workshop for the prefabrication on ground was set up under a metallic tubes structure: light metallic ribs and tools were made for adopting the on-site casting method, by welding thin metal sheets to light metal trusses.

Besides its fast dissemination between the industrialized system, the Borghesia's prototype was fully manufactured and, as crafted object, matched the original dimension of Italian industrialization: so, even, in the following years, the «AL.FA slab» continued to be constructed only on-site, demonstrating also a great versatility to the different span required.

The «AL.FA slab», however, was not the only structural element that Favini filed as utility models: throughout the 1960s, he developed a whole catalogue of "ornamental structures" including beams, pillars, roofing segments and shed roofs, to be fabricated in situ, supported by craft metal carpentry[11]. (Picture 6)

5. MANGIAROTTI'S INDUSTRIALIZED TRILITHON

During the years that Favini was progressing with in-situ prefabrication, Mangiarotti established himself as artist and de-

[10] Central State Archive, Rome, Patent Fund, Favini, A., utility model n. 109864, "Elemento prefabbricato di copertura con costola di irrigidimento" [Prefabricated floor covering with stiffening ribs], 4th January 1967.

[11] Central State Archive, Rome, Patent Fund, Favini, A., utility model n. 122032, "Elemento prefabbricato di copertura con doppia nervatura di irrigidimento" [Prefabricated roofing element with double stiffening ribs], 13th march 1967; Favini, A., utility model n. 122100, "Copertura piana ad elementi prefabbricati con intercapedine"[Flat cover with prefabricated elements with caved], 3th april 1967, Favini, A., utility model n. 134753, "Copertura prefabbricata di pannelli piani a cassone" [Prefabricated deck top cover], 10th January 1969.

Picture 6. Favini's "coppone AL.FA." in the work site of Borgoresia (Historical Archive of Milan Politecnico, Aldo Favini Found, Rome)

signer on the international scene (14). This position enabled him to bring the new consumer elite of italian entrepreneurs as potential client, obtaining the realization of a number of industrial buildings (15).

In 1964 he was involved to design the «Elmag» fectory at Lissone: a 2400m² space with 16 metres long free spans. Industrialisation of building was still the point in Italy, as it was the use of reinforced concrete (16).

The building featured the two issues epitomized an industrialized structure made with such an «artificial stone»: 3 elements – pillar, beam and roofing segment – were combined following the trilithic static concept.

Gravity featured the static behavior of the ensemble – except for minute metal ligatures added in situ – and ideally referring to the classical order, «each piece was subject to uniform established proportions, regulated by the office that each part had to perform».

The use of reinforced concrete played a crucial role, as it was easily casted in form resistant profiles and in suitable geometric assembly, working by friction. Additionally, with precompression the stress flows could easy directed and «stone pieces» could became lighter: the post and lintel structure enhanced a new slender, revealing even the timber structural origin of the classical temple.

At Lissone - analogically transposing this figure - high pillars, slender beams and corrugated roofing segments embracing the equilibrium of stresses and were clearly superimposed on each other working by gravity and friction.

All the elements of the structure were prefabricated in the factory and assembled in situ, acting the intersection of a traditional industrial process with the craft dimension of the work site. In the «Elmag»'s area, indeed, the elements forged in the factory were assembled with rudimental supports and devices: pillars were hoisted by a trellis winch and beams were put in place with a crane, manually operated by only two workers climbed up onto the pentagonal capitals.

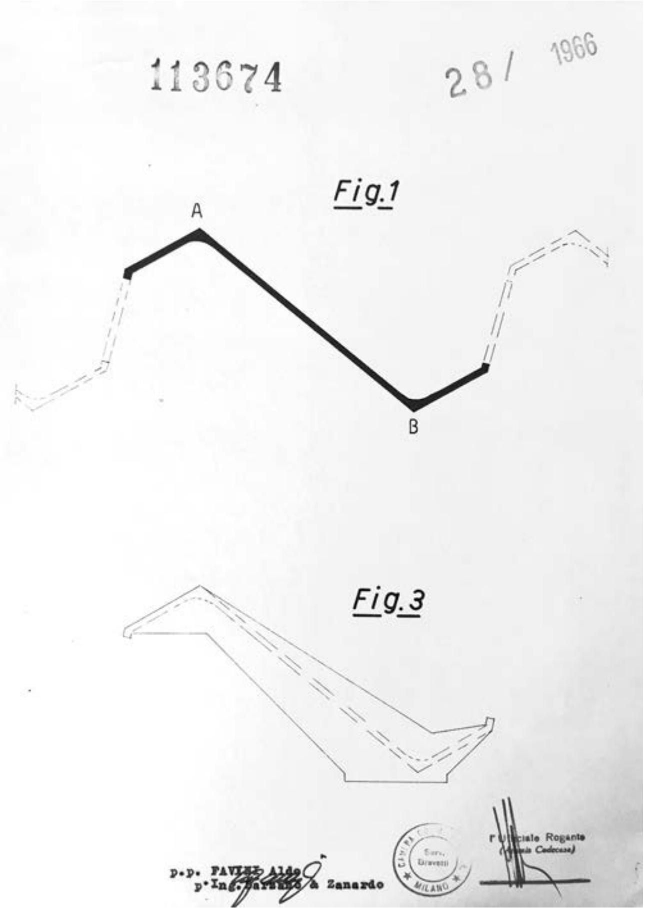
In 1969, once the construction of the «Elmag» factory has been completed, Mangiarotti was involved in the design of the «Lema» corporate building at Brianza.

The styling of new system of industrialized elements in reinforced concrete was put on premise.

To enhance the design practice started for the «Elmag», Mangiarotti aimed to drive the study of the structural elements to the detailed definition of the production process, including the carpentry drawings.

On this purpose, a design's collaboration with three structural engineers – Gianni Colombo, Alberto Vintani, and Giulio Ballio (whose experience also included a period in Favini's studio) – was started.

The system, tracing the «Elmag» one, based on 3 structural elements – pillar, beam and roofing segment – drawn by



Picture 7. Favini's utility models for roofing segments: "coppone AL.FA." and "shed Z-shaped", 1966 (Central State Historical Archive, Italian Office for Patents and Trademarks Found, Rome)

Mangiarotti and detailed, at the same time, by the engineering approach. New chamfers, questioned by the moulding of metal frames, and new sections occasioned by the load-bearing structure were promptly introduced and dealt in conjunction with Mangiarotti's shapes.

To realize a continuous and complanar intrados, the system – compared to the «Elmag» – introduced a reversal in the dimensions of the beam and the roofing segment (the beams became shorter than the roof segment) and required the extensive use of prestressing, to strengthen the horizontal elements. Beams and roofing segment were shaped on an inverted U-profile, functioning both as optimal resistant form and as geometric assembly working by friction with the pillars. (Picture 8)

Furthermore, to optimize the global behavior of the structure, conceived ever for gravity and compression, a series of complementary components was locally added (such as precast foundation to anchor the pillars and a system of metal connecting between the elements) and variation of the rebar of pillars, beam and roofing segment was adopted according to their position.

Even if the structural «tricks», due to the joined work of Mangiarotti and the engineers, remained unrevealed in the prominent figure of the structure it led to enhance the system even in technical terms: indeed, overtaking the state of art of the more standardized system of industrialized building, the structure, filed to the Italian Patent Office, obtained the registration in first class of inventions in 1972. The patent was followed by a second one, filed by Mangiarotti to protect the design of a further idiomatic «structures in prefabricated concrete elements» designed in conjunction with the three engineers for the «sacie» construction company[12]. (Picture 9) «Sacie» was looking to devise a new system of prefabricated elements for single-stage buildings with a structural grid of 7.2 x 7.2 metre. Prestressing was not even questioned and it was possible to conceive a structure to be precast in factory or in-situ. (Picture 10)

The elements were few and simple: a column with a square capital, the beam and the roofing segment. The structural pattern consisted on four pillars, perimetric beams completed by the multidirectional plot of the roofing segment. Furthermore, to envisage a series of variations in length, the structural system included different components of various spans fitted by hidden structural and technological solutions: to handle dissimilarities in stress and optimize the overall behavior of the structure the corner pillars and capitals, to face even the bending stress, disguised a double reinforcement and minimal variation of the profiles were introduced to include the network of the electric equipment.

Between 1976 and 1979 Mangiarotti was in charge of the Pederzoli FIAT dealership in Bussolegno. Even if, in those years, prefabrication had been tending to finally disappear from the italian architectural debate, Mangiarotti continued to offer an ideational and executive praxis inherent in the design by componets.

So, his final undertaking in the field of reinforced concrete industrialised construction, alongside the Ballio-Colombo-Vintani engineering team, was started.

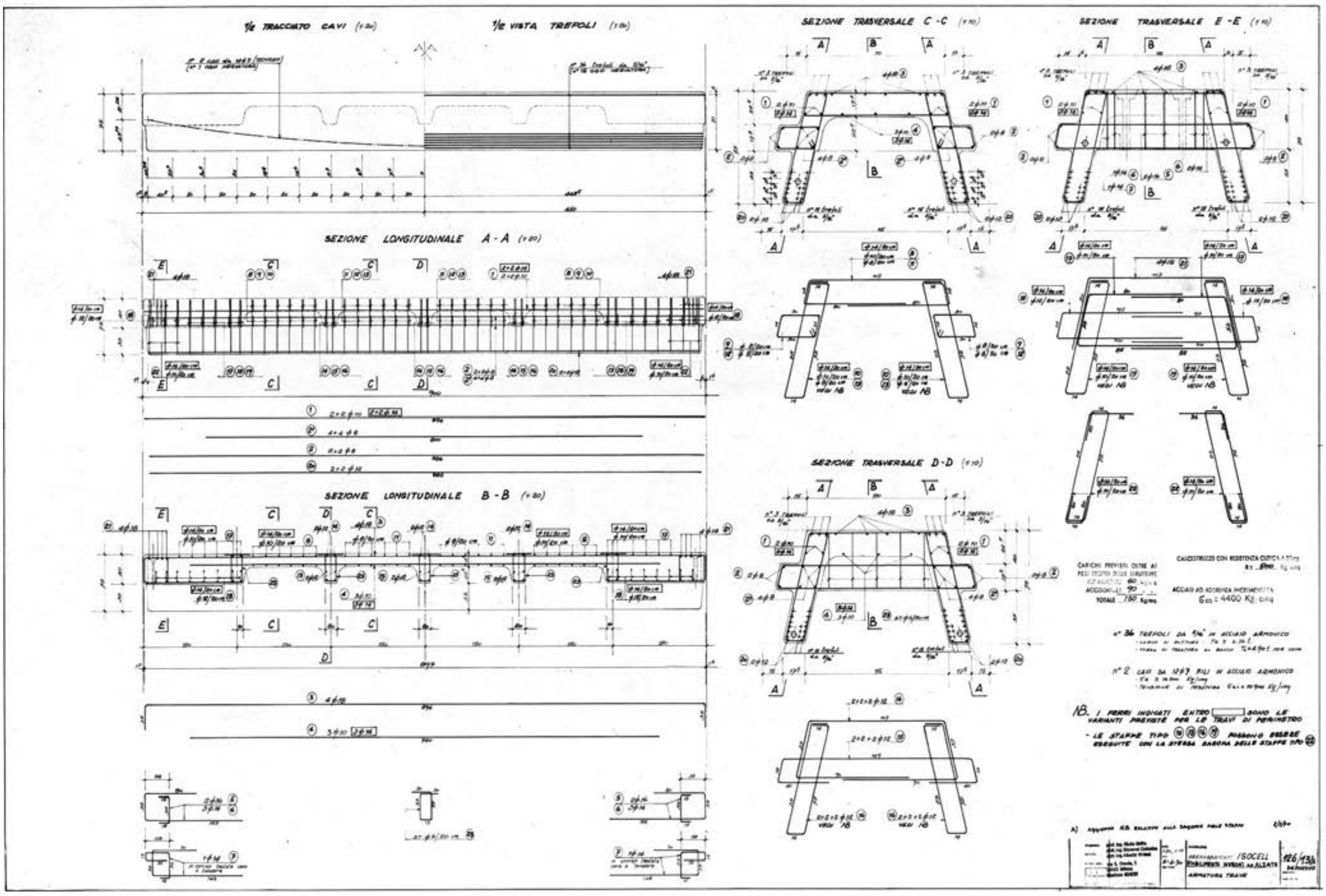
The showroom had challenging spans for a precast reinforced concrete structure: the over 20 metres free spans, defied also the actual regulations concerning the use of prestressed precast units.

The structure was based of the usual series of three elements: pillar, beams and roofing segments. The idea of the beam set in the thickness of the slab with a constant intrados was abandoned.

While the design of pillars and roof segments became simpler, the beam embodied the features of the load-bearing structure: in the challenging dialectic between designing its shape and engineering it, the beam assumed an «inverted y» section. Supported by H-shape pillars, casted in situ, the beam presented a large overhang, that characterize the portico of the entrance area of the building: to maintained constant its profile, the resistant section had to be thick enough to incorporate the 14 prestressing tendons and the reinforcement of the upper rebar in the cantilever.

The form of the beam was sought tenaciously, as the series of sketches revealed: started in autumn 1976, when regula-

[12] The two system were used only on rare occasions. After the presentation of the prototype at the SAIE Exposition, the first (and last) building realized with this Sacie system was the entrance pavilion of the FEG plant in Giussano.



Picture 8. Mangiarotti, Ballio-Colombo-Vintani, Lema System of precast prestressed componets, 1969 (Private Archive of "BCV progetti", Milan, courtesy of Giulio Ballio and Alberto Vintani)

tions concerning prestressed reinforced concrete structures had been recently updated, and only ended in march 1978 when ballio-colombo-vintani were starting to use their first rudimental electronic software for their calculations.

The final product of this long conjoined work was a «design object» that retained the legibility of its process of industrial production - its totemic profile cut through by elliptical curves spoke us clearly about the moulding of the metal frameworks - displaying an ideational and executive praxis inherent in the design by componets, exactly when prefabrication had been tending to disappear from the architectural debate.

6. CONCLUSIONS

Throughout the 1970s, whilst the standardisation that was pervading the country was starting to affect even large-scale structures and gradually turning them into featureless products embodied only technical issues, the structures designed by Favini and Mangiarotti still retained an individual and masterly character.

The structural design of the northern italy developed, indeed, an autonomous perspective firmly established in the local history.

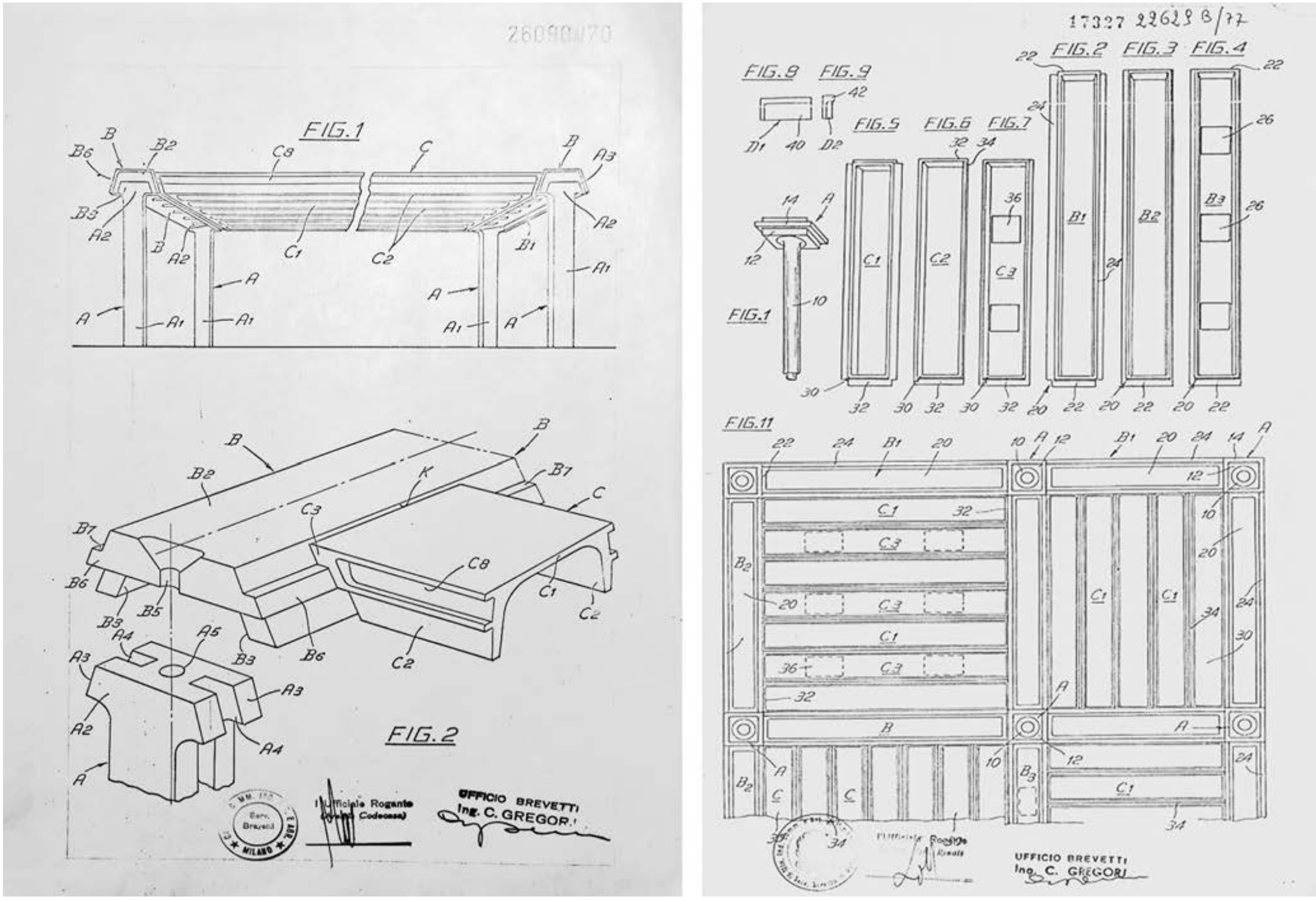
The German occupation of Northern Italy after the Armistice with the Allied and the exile in Switzerland of university students seeking refuge, the industry-driven Reconstruction, and the development and success of italian product design (17), constituted a common background for an entire generation of engineers, designers and entrepreneur.

In the internment camp of Lausanne University, students of engineering, architecture and design came face-to-face to address the emergency of the aftermath of WWII, in a transversal debate dealing with all aspects of the project praxis and theories, from interior design to infrastructure: structural designers familiarized both with the foremost scientific models and process of building, considering technique as the befitting tool for the a democratic governance of Reconstruction (18).

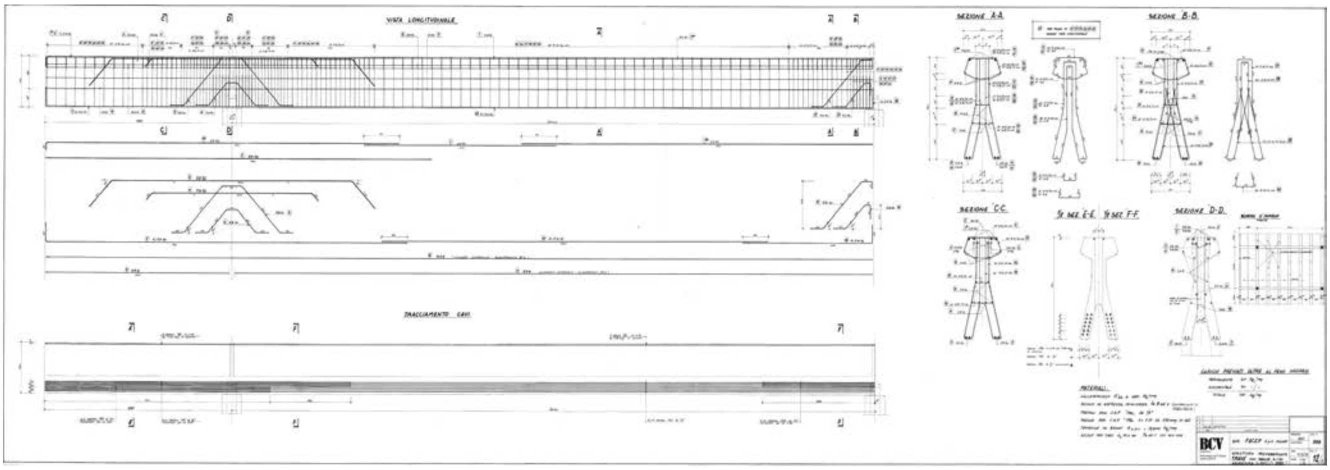
Once back in Italy, the widespread build of new factories was crucial and, as the opportunity to test and stress what they'd learned in Switzerland, involved engineers to undertake an original topic of structural project: the intermediate structural span structure, conformed to the rapid erection of the building.

Reinforced concrete was an imposition of the economic-productive system and industrialization of the building process the general goal.

With the combined use of conventionally opposed scientific models as form resistance and pre-compression and deeply intertwined handmade construction and industrial prefabrication, reinforced concrete structural elements could be cost effective serially manufactured, moulded and cased in relation to their static capacity.



Picture 9. Mangiarotti's patents for precast reinforced concrete system of components, 1970-1972 (Central State Historical Archive, Italian Office for Patents and Trademarks Found, Rome)



Picture 10. Mangiarotti, Ballio-Colombo-Vintani, Pederzoli System of precast prestressed componets, 1976 (Private Archive of «BCV progetti", Milan, courtesy of Giulio Ballio and Alberto Vintani)

The solution unbalanced the orthodox vision of the Italian engineer but it was able to reveal reinforced concrete as an actual competitor to steel in the industrialization process.

Considered in the international panorama, Favini and Mangiarotti's structural design enhanced the repertoire of the italian school, stood out in the unavoidable anonymisation of the industrial building process.

Moving closer to the coeval international achievement of Italian design, Favini and Mangiarotti brought structural design into the production of standard components: beams, roofing segments, and pillars (shaped with elegant chamfers and profiles) became artefacts materializing, in the specific field of structural engineering, the modern utopia to transfer art to industrial production.

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