Engineers in Italian Architecture: the Role of Reinforced Concrete in the First Half of the Twentieth Century

Tullia Iori

This document summarizes the results of a research project which addressed a range of issues regarding the development of reinforced concrete in Italy (Iori 2001).

How did this new technique begin to spread at the end of the nineteenth century? To what extent was this new technique imported from abroad? And how did foreign systems set off its autochthonous development? What role did the post-earthquake reconstruction of Messina and Reggio play in this? Moreover, what role did Italian researchers occupy in the international debate on the adaptation of a classical theory to a non-homogeneous material? And subsequently, how were the limitations placed on the use of steel during Italy's autarchic period overcome? How did the development of reinforced concrete continue? And while this technique became widespread in daily construction work, how did it develop in the experimentation of greater works?

Based on previously barely-utilized sources from the Patents Office Archives and specialized engineering magazines, this study reconstructs the use of reinforced concrete in construction work in Italy from its first uses up to the Second World War. The study focuses on a sequence of more than one thousand inventions, both Italian and foreign patents, which determined the many formulations and subsequent revisions of this technique. It attempts to bring order to a vast debate on the structural theories and calculation methods, also employed in Italy, which accompanied the development of reinforced concrete.

This study is part of a lager research project conducted by Sergio Poretti and a close-knit Architettura Tecnica Unit at the University of Rome, Tor Vergata on Construction History. The research carried out by this unit follows a complementary course: on the one hand representative monuments are studied (in-depth radiographic analyses of construction and architectural elements), while on the other, the development of specific construction techniques is reconstructed. The objective is to delineate the development of a special sector, the material history of architectural and engineering construction in twentieth-century Italy (Poretti 1997; Poretti 2004).

THE ADVENT OF A NEW TECHNIQUE (1850-1900)

Between 1850 and 1900, experiments were conducted, both in Europe and in the United States, on the use of a new material created by combining two very widely employed industrial products: cement and structural iron. This new material was called *béton armé*.

How was Italy involved in this experimentation?

Construction techniques in Italy were certainly unique. Although the general lag in industrialization, and consequently in the iron and steel industry, had not completely blocked the development of iron architecture, it certainly slowed it down. Construction work, however, was undergoing a period of interesting evolution after many centuries of relative standstill. In Piedmont, in particular, Alessandro Antonelli rationalized reinforced masonry in boldly static monuments. Cement, which was just beginning to be produced industrially at this time, was exclusively used for decorations and finishings through a technique known as "artistic cement".

In fact, Italy did not directly participate in the pioneering experimentation phase of what was referred to as béton armato. Nonetheless, the construction industry was very interested in this new technique. Thus, the most important patents protecting this technological improvement were also deposited in Italy, although the divulgation and application of these new techniques was much slower (Monier 1883).

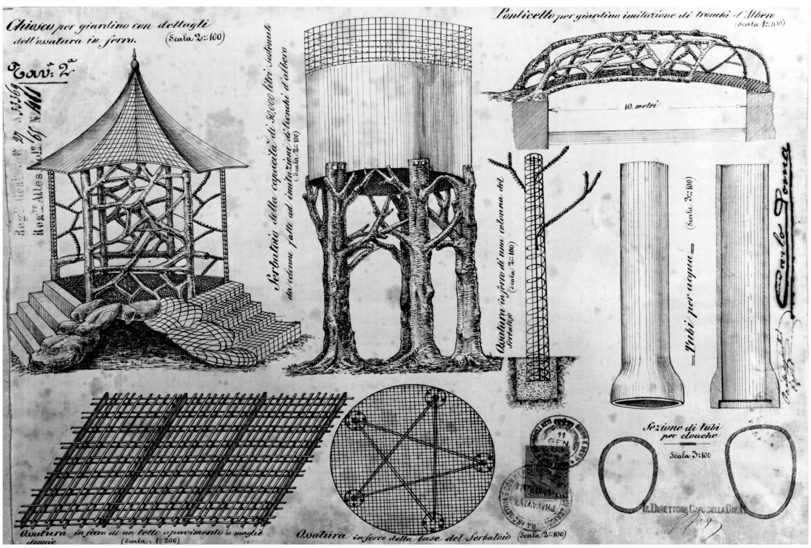

Figure 1. Italian Patent n. 33369 by C. Poma. *Costruzioni di beton e ferro. Miglioramento del sistema Monier*, 1893 (Archivio Centrale dello Stato, Rome, Italy)

François Hennebique, a shrewd entrepreneur holding an innovative patent, played a key role in the diffusion of this new material, especially in Italy, where he set up a very efficient series of branch agencies (Hennebique 1892; Nelva and Signorelli 1990).

In the meantime, the increasingly daring reinforced concrete applications in Europe set off an animated debate, primarily involving French and German scientists, who focused on the formulation of a less empirical "rational" calculation theory for the new material than those that had been previously made by the patent owners.

The importation of foreign systems led to widespread experimentation, which soon engaged the entire local enterprise system. By the mid 1890s, a vast number of local patents had been deposited that often were sophisticated variations of the already tested foreign systems (Baroni and Luling 1899). **(Fig.1)**

The application of these new techniques was not limited to the leading construction firms that had quickly converted to the new technology. Newly created companies specialized in the use of reinforced concrete construction were also quick to make the most of the new development. The number of buildings and monuments created, both with Italian and foreign patents, right before the turn of the century demonstrates the interest of local enterprises in this new material and its incessant diffusion. **(Fig.2)**

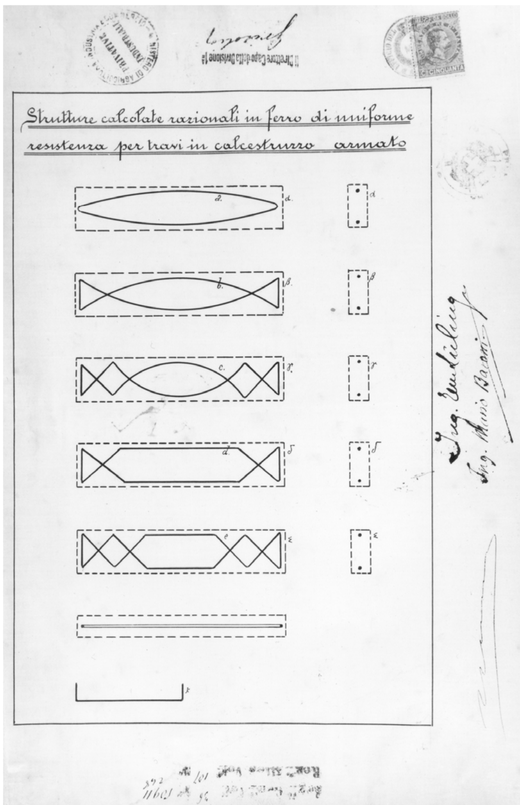

Figure 2. Italian Patent n. 50911 by M. Baroni and E. Luling. *Strutture calcolate razionali in ferro di uniforme resistenza, per travi in calcestruzzo armato*, 1899 (Archivio Centrale dello Stato, Rome, Italy)

DIFFUSION (1900-1915)

By the turn of the century, the pioneering period of reinforced concrete had come to an end both in Italy and in Europe. It was officially recognized as an invaluable material and was commonly used in construction work.

The new construction technique became part of the professional training of engineers. Manuals that addressed the main issues related to the use of reinforced concrete and established basic procedures and standards for its application were published. In universities, science and mechanical construction courses embraced the technique and graduates were finally equipped with the information necessary to safely apply the various systems (Guidi 1901, Canevazzi 1901).

At the same time, mainly due to the still many computational uncertainties, the increase of uncontrollable construction systems and the collapse of buildings under construction, many European countries adopted a series of cautionary measures, which raised further debate. In Italy, the Ministry of Public Works approved a series of regulations governing reinforced concrete construction work to guarantee the safety of public works (Ministero dei lavori pubblici 1907).

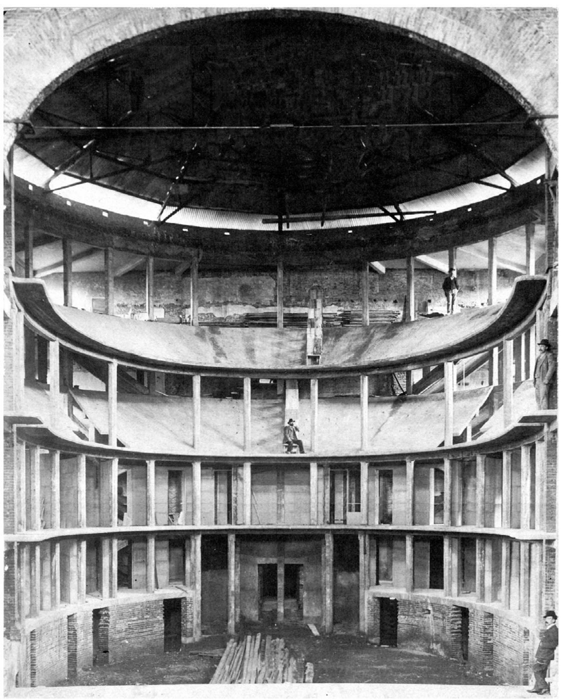

Figure 3. Social Theatre in Rovigo built by G.A. Porcheddu, following Hennebique Patent, 1902-1904 (Danusso 1928)

However, the diffusion of the new material and its widespread use in the construction of residential buildings and public infrastructures required a new national law. The thousands of structures erected by Hennebique agencies were mirrored, in the many new technical magazines dedicated exclusively to reinforced concrete construction work, by the applications carried out by the many specialized construction companies in constant competition with one another. **(Fig.3)**

In the meantime, once the framework-concrete mechanism had been firmly established, patent experimentation turned to individual construction elements. In particular, floor construction techniques, in which reinforced concrete was used to replace the traditional construction methods (Ghilardi 1902, Frascardi-Calvino 1907, Danusso 1911). The new inventions showcased the first prefabricated beams and the first lug bricks for the construction of mixed element floors, which were soon to undergo an extraordinary development in Italy. **(Fig.4, Fig.5)**

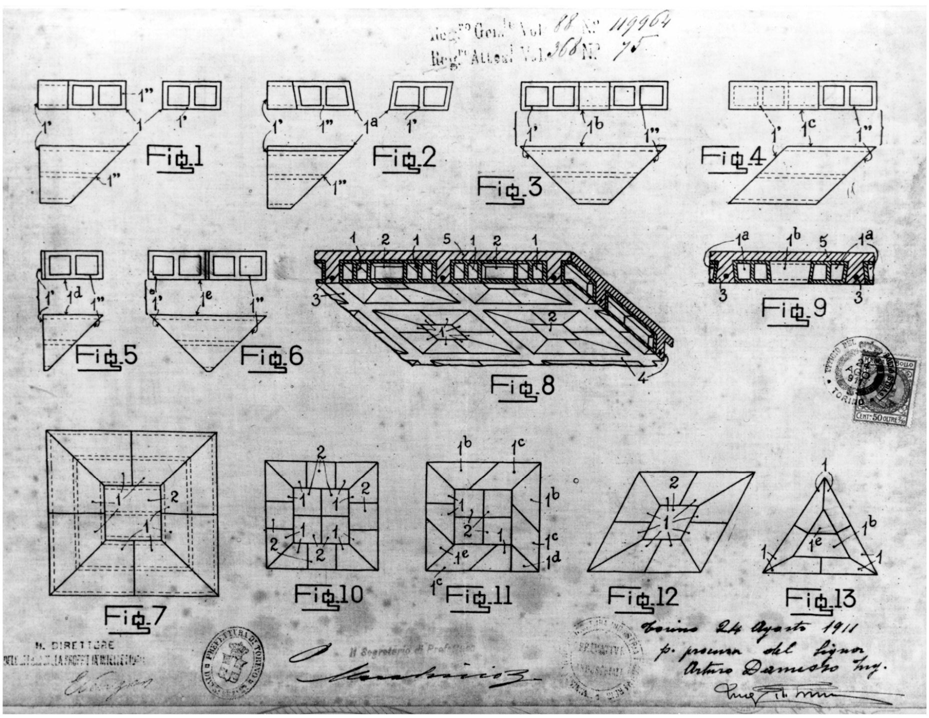

Figure 4. Italian Patent n. 119964 by A. Danusso. *Perfezionamenti nei solai in cemento armato a doppia serie di travi ad angolo tra di loro*, 1911 (Archivio Centrale dello Stato, Rome, Italy)

A decisive stimulus for the definitive affirmation of the reinforced concrete technique came in the aftermath of the 1908 earthquake in Messina and Reggio Calabria. The anti-seismic framework became widely employed in the twenties and profoundly conditioned the way in which reinforced concrete was employed in Italy.

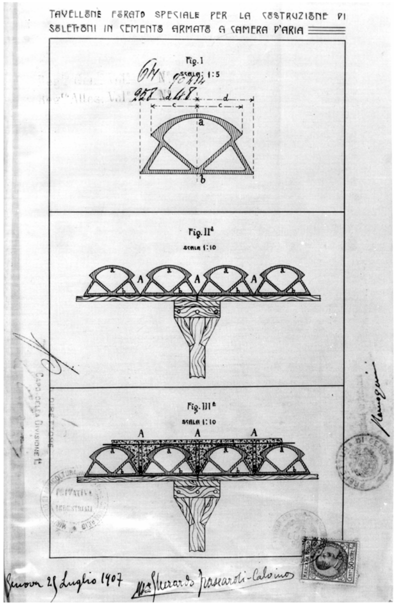

Figure 5. Italian Patent n. 90414 by G. Frascardi-Calvino, *Tavellone forato speciale per la costruzione di solettoni in cemento armato a camera d'aria*, 1907 (Archivio Centrale dello Stato, Rome, Italy)

In the meantime, the classical computation theories, which had since been perfected, were employed in the erection of large works. The *Ponte Risorgimento*, a bridge erected in Rome in 1911, was to influence many of the theoretical debates of the coming years. It played a key role in comprehending the limits of the elastic behaviour hypothesis of reinforced concrete. **(Fig.6)**

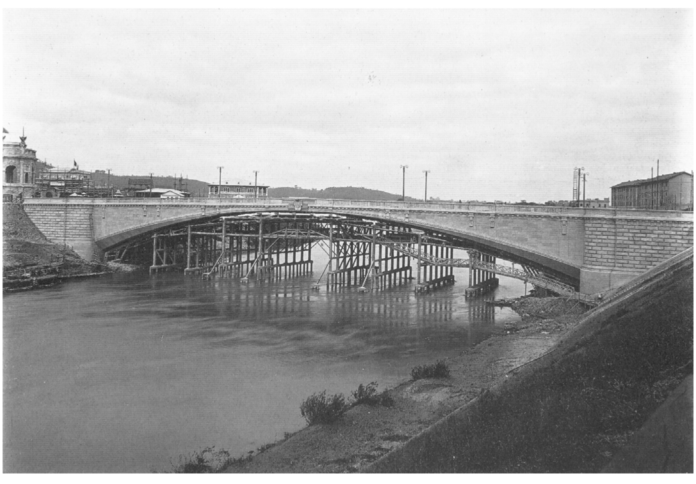

Figure 6. Risorgimento Bridge on Tiber in Rome, 1911 (Nelva and Signorelli 1990)

STANDARD USE OF REINFORCED CONCRETE (1915-1935)

Starting with the post-war reconstruction and throughout the nineteen-twenties, the use of reinforced concrete construction had become a common construction technique.

In this phase, characterized by the erection of public residential buildings, this construction system, which proved faster and cheaper than traditional systems, turned out to be perfect and was often used together with load-bearing masonry in a mixed system.

The reinforced concrete technique was no longer the exclusive domain of patents and specialized firms. It had become part of mainstream professional engineering and was employed by many small and medium sized companies. In order to simplify the work of neophytes and expedite expert projects, (not always rigorous) manuals, abacuses and charts became readily available along with new mechanical tools such as slide rules and the first calculators. **(Fig.7)**

Figure 7. One of the first italian manual for reinforced concrete design:
Il cemento armato by Luigi Santarella, 1926.

The fact that the this technique became increasingly accessible to companies and project designers, who were not necessarily qualified, called for a more scrupulous appliance of the existing laws and, in particular, the regulations regarding executive project aspects. The outdated law issued in 1907 was reviewed in 1927 and extended to apply to all construction work, both public and private.

In the meantime, the scientific community continued to study the material and refine the knowledge of previously ignored parameters. Industry continued to improve and transform production techniques, privileging artificial cement over natural cement, which had grown scarce. This process of refinement lead to the invention of special use cements.

During the latter half of the nineteen-twenties, a series of circumstances drastically changed the course of Italian construction techniques. And the role of reinforced concrete changed, too. Within a couple of years, in fact, the Fascist regime had drawn the construction sector back into a state of corporatism. The reaction to the great crisis of 1929, which had interrupted the development of construction work, spawned the development of new techniques. Finally, this all took place concomitantly with the beginning of the great debate on modern architecture. **(Fig.8)**

Figure 8. First Italian exhibition of "Rational Architecture", 1928:
a reinforced concrete pillar as *manifesto* (Private archives)

What role did the reinforced concrete technique play in this transformation process? And how did the reinforced concrete technique evolve as a result of this transformation?

While technological experimentation was directed towards large structural works, research investigated the shape of reinforced concrete frameworks in relation to the search for new forms and worked towards the definition of a new architectural language (Poretti 1990, Poretti 1999). Construction methods evolved rapidly and involved architectural culture. The results of this phase are witnessed in the works carried out in the first part of the nineteen-twenties, before the autarchic period changed the conditions once again. **(Fig.9)**

Figure 9. Post Office Building in piazza Bologna, Rome, in construction. Mario Ridolfi, 1933-1935 (Poretti 1990)

AUTARCHIC EXPERIMENTATION (1935-1943)

The Italian aggression of Ethiopia and the subsequent economic sanctions raised against Italy by the Society of Nations, in November 1935, gave rise to a critical phase in the economic policy of the Fascist regime. The protectionist orientation aimed at making Italy self-sufficient, which was part of corporatism, became increasingly stringent and lead to the most intense phase of autarchy, which was also motivated by the subsequent military decisions.

In construction work, as in all other productive sectors, the objective of becoming independent from all imported material became a determinant factor. This sparked a fierce debate, but also increased the range of experimentation aimed at finding new solutions with a greater "national value." The use of reinforced concrete was dependent on foreign supplies both for the wood, used for the moulds, and for the framework iron. Thus, the technique was accused being anti-autarchic. Notwithstanding the fact that the "gold-cost" ratio revealed that it was more convenient than other building techniques (using steel or load-bearing masonry), the need to reserve all iron for the military effort condemned it. The use of reinforced concrete became severely limited from 1937 and by 1939 was completely banned.

However, the restrictive measures did not stop engineers and researchers, who continued to study ways to make reinforced concrete more "autarchic". There were two main lines of research (Poretti 2004, Capomolla 1994).

A more "traditional" line of research turned to a long-term approach and hypothesised that once the war was over, the use of reinforced concrete would pick up again with nationally produced iron. Thus, research was aimed at economizing its use in frameworks by employing higher precision calculation methods, greater project care and the use of materials with higher performance potential (high resistance cement and steel).

The other line of research, which was more innovative and aimed at reaching immediate results, returned to the experimentation that had been carried out right after the war, when supply problems and the high cost of traditional building materials had fuelled research on alternative, nationally-available materials. As had already been proposed during the period of "building frenzy", wood and new materials, such as bamboo, asbestos-cement and aluminium, were proposed as possible materials for reinforcing the frameworks **(Fig.10)**.

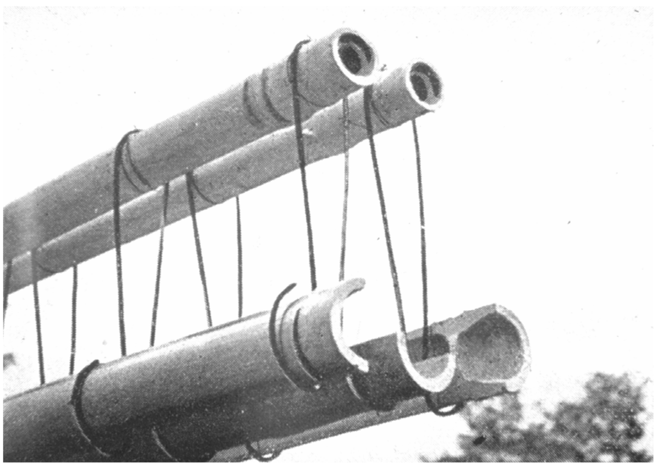

Figure 10. “Bamboo-beton”: Bamboo stems replace steel rods in beam (Paoloni 1938)

In order to reduce dead weights in buildings, the use of cement blocks and perforated bricks was increased together with pumice-based elements and materials composed of other waste products.

A law was also passed to allow the construction of mixed-element floors without superior slabs and horizontal construction methods with reduced frameworks were studied. As the lack of framework iron increased, experimentation turned to the construction of floors without iron **(Fig.11)**.

From the Miozzi to the Neumann patent, dozens of systems based on the traction resistance of bricks and cement claimed floor construction stability without the use of iron (Miozzi 1937, Neumann and Boldrini 1940). This final phase of research, which was abandoned right after the war, often provided unexpected results that were not justified either by calculation or material characteristics.

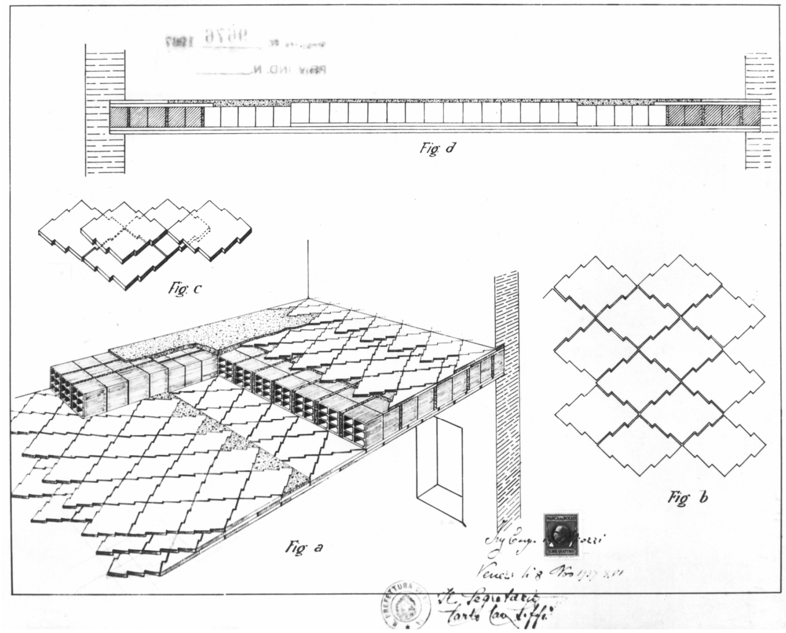

Figure 11. “No iron floor”: Italian Patent n. 364671 by E. Miozzi, *Nuovo tipo di solaio in laterizio forato senza impiego di ferro,* 1937 (Archivio Centrale dello Stato, Rome, Italy).

GREAT WORKS (1920-1943)

Starting in the mid nineteen-twenties, as we have seen, reinforced concrete gradually became an everyday construction material. The innovative turmoil that had accompanied the development of this material shifted from construction elements to application methods as part of the renewed building conception that progressively lead to a complete transformation of the existing relation between load-bearing masonry and framework.

So, what was happening in the great works sector? In order to answer this question, we have to step back to the beginning of the nineteen-twenties and follow the experimental course of the building techniques relevant to structurally important works.

Manuals and experience were sufficient to erect normal reinforced concrete buildings; technological and theoretical experimentation was directed at larger structures. In fact, this was what interested the specialized firms, which left ordinary construction work to the many small companies that had blossomed, in order to concentrate on projects in which accumulated experience was indispensable. The most recent industrial and theoretical inventions, from high-performance artificial cement to building site machines and from sophisticated frameworks to intricate calculation theories were applied to these projects.

Starting in the mid nineteen-thirties, the Fascist regime's economic policy condemned the use of the little available autarchic reinforced concrete and eventually forbid its use in both public and private civil constructions. However, if this ban had been rigorously applied to the great works sector the building sites would have ground to a complete halt. In these cases, the projects were reviewed in order to minimize the use of iron. On the one hand, the resistance values of materials were arbitrarily increased and isostatic structures were employed in order to allow preciser calculation and, consequently, optimal member use. On the other hand, a process of involution set in: bearing distances diminished and the use of reinforced concrete shifted to "less reinforced" concrete and then to simple concrete. Finally, *forte sesto* arches were made in traditional masonry as it was considered more autarchic.

Although autarchy brought about an involution of practical applications, it also stimulated research into rational structures, which according to the fundamental principles of structural engineering also means less expensive structures. Old solutions that had been put forward in the pioneering phase or this material resurfaced against the attempts to substitute or eliminate iron as new technological developments (new cements, special steels) and the increased knowledge of these materials (cement traction, framework release and viscous phenomenona) allowed these techniques to be fully developed.

The objective of autarchic experimentation was to radically transforming the relation between iron and cement and overcome the intrinsic limits of reinforced concrete. This research followed two routes (Iori 2003).

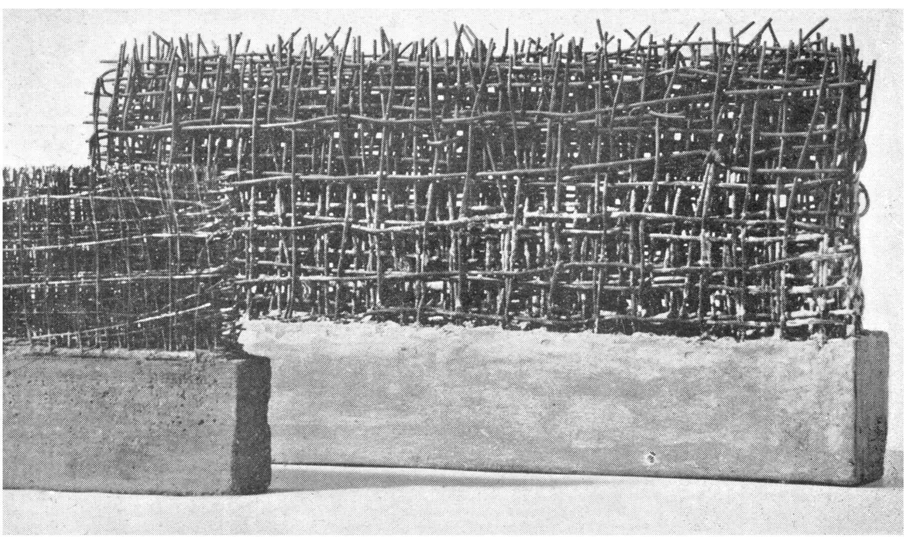

Figure 12. Pier Luigi Nervi “Ferrocemento”, 1943 (Nervi 1945)

One route was represented by the thin structures that starting with Lambot and Monier's cemented iron and European research on vaults and shells brought Pier Luigi Nervi to experiment on highly-reinforced reduced thickness structures. This lead Nervi to the invention of *ferrocemento* a new homogeneous, isotropic and elastic material that would characterize his entire post-war production **(Fig.12)**.

The other route also led to the creation of a new material, which was erroneously called "pre-compressed reinforced concrete" in Italy. Research conducted at the beginning of the century was used to invert the role of the two basic materials of reinforced concrete: iron no longer had to absorb the traction that the cement couldn't support, but became the means to impress the conglomerate with the necessary constraint to absorb all the stress.

A lively debate was raised in Italy regarding the far more efficient experimentation conducted in Europe by Eugène Freyssinet, Franz Dischinger and Ulrich Finsterwalder, which lead to important theoretical contributions such as those made by Gustavo Colonnetti **(Fig.13)**.

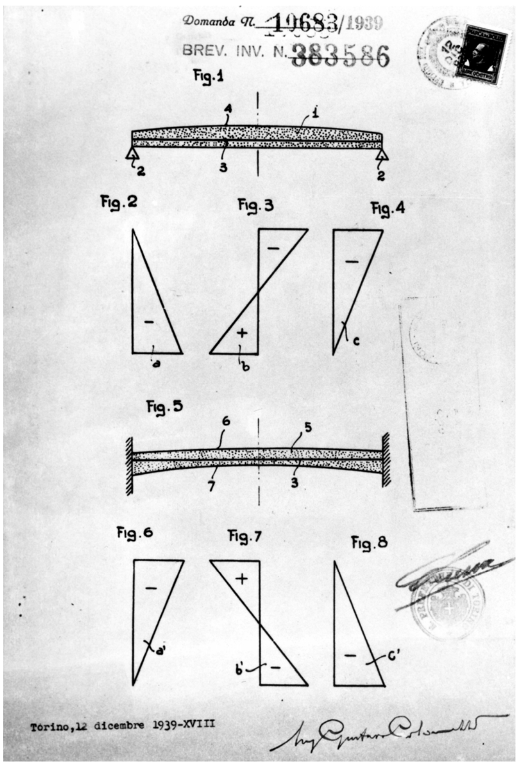

Figure 13. Italian Patent n. 383586 by G. Colonnetti, *Trave armata ad armatura preventivamente tesa*, 1939 (Archivio Centrale dello Stato, Rome, Italy).

In the years preceding the war, he set the premises for important developments that were to be widely used during the reconstruction period and which were to decree international recognition for another Italian engineer, Riccardo Morandi (Iori 2005).

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