THE IMPORTANCE OF SEISMIC LEGISLATION AND REINFORCED CONCRETE IN THE RECONSTRUCTION OF THE CITIES OF THE STRAIT OF MESSINA

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1. Introduction

In light of the relationship between seismic legislation, the introduction of new construction techniques and urban planning, the reconstruction of the cities of Reggio Calabria and Messina after the disastrous earthquake of 1908 can undoubtedly be considered an interesting field of analysis and study. Immediately after the earthquake, in fact, many questions arose regarding aseismic legislation and the role that it should have played in the reconstruction of the two cities of the Strait. [1]

After the first phase of emergency assistance which, both in Reggio and in Messina, coincided with the construction of barracks in debris-free areas on the edge of the old town, the academic community then concentrated on the lines to be followed in preparing the regulatory planning schemes for the two cities. Two important questions, moreover, needed an answer: on the one hand, the need to determine the most suitable *sites* for rebuilding the city; and, on the other hand, the need to specify the most appropriate building techniques to prevent any collapse in the event of future earthquakes. The necessity of providing immediate answers to the problem of reconstruction in the areas affected by the earthquake of 1908 represented a decisive factor in the development of a specific field of engineering: *anti-seismic engineering*. [2]

Following the earthquake, the anti-seismic framework developed in those years successfully established itself throughout the national territory, deeply influencing the way reinforced concrete was used in Italy. The rapid spread of the material, already employed in many building types and infrastructures, soon highlighted the need for a more specific national legislation. A fundamental role in its preparation was assumed by the *Associazione italiana per gli studi sui materiali da costruzione*, a centre for the study of construction materials of the Ministry of Public Works. The drafting of these regulations determined that each construction in reinforced concrete, had to be built according to an executive project with static calculations signed by an engineer. Provisions were made also regarding the quality of the materials and the executive procedures of the works. For example, strict rules were imposed on the packaging of mixtures, on the formworks for pouring the concrete into and on the time needed for

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dismantling; it also indicated that no work in reinforced concrete could be used before it was properly tested. [1]

The planning schemes of the two cities of the Strait were approved in 1909, a few months after the earthquake, to highlight the symbolic rebirth of the cities. To fully understand the social and cultural conditions that influenced the realization of these planning schemes, special attention should be given to the impact that this natural event caused in the field of scientific research. The extent of the destruction caused by the earthquake started a fierce debate on the most appropriate technology to be adopted for building in areas prone to seismic risk in such a way that the theme "Constructing in seismic areas" was the main subject of the "XII Congress of Italian Engineers and Architects", held in Florence in 1909. Among the various proposals made in this congress, it is important to remember those designed by the "Garden City Movement", which pointed out as the most suitable solutions: low-density construction, development in extension of inhabited areas and use of advanced technologies, such as reinforced concrete and composite structures. The predominant concept was that the new buildings would be a maximum of two floors, with roofing and ceilings that were uniform and light and had massive foundations.[1] [2, 3]

As a result, reconstruction methods used in both cities were strongly affected by the highly restrictive anti-seismic legislation and strict building code that were adopted. The planning schemes for the cities of Reggio Calabria and Messina, respectively the "Piano De Nava" and "Piano Borzì", must be re-read keeping in mind two basic principles: on the one hand, maintenance of the safety principles guaranteed by the technical standards for seismic design and, on the other, consideration of the nineteenth century theories on health and hygiene that strongly conditioned the drafting of these plans. Thus, for example, the elimination of unhealthy urban areas was achieved through the creation of two "new" cities, which extended lengthways and were divided into regular blocks based on a reticular road system, where a decisive role was played by the influence that the technical rules had in defining their "shape". In fact, the use of reinforced concrete and a specific relationship between building height and road width, determined their "shape", which still exists today and has allowed these cities to become "newer and more autonomous" than the pre-existing ones. [4]

2. Seismic legislation: preventive methods in the urban planning of the two cities of the Strait

A few months after the disaster, the problem of reconstructing the areas destroyed by the earthquake was dealt with even greater conviction by special committees whose preliminary work, involving technical and scientific knowledge, became important starting points for the elaboration of the new seismic legislation to be adopted in the areas affected by the earthquake. In particular, the study conducted by the "*Regio Istituto di Incoraggiamento di Napoli*" and prepared in 1909 by a special commission of experts, entitled *Contributo alla ricerca delle norme edilizie per le regioni sismiche*, had the task of taking stock of the situation on earthquake standards up to that moment in Italy and indicating the main studies published on the subject.[2] [5]

On the 18th April 1909, the seismic legislation, adopted in the reconstruction of the areas of the Strait was finally approved through the enactment of Royal Decree no. 193 (*Norme tecniche ed igieniche obbligatorie per le riparazioni, ricostruzioni e nuove* *costruzioni degli edifici pubblici e privati nei comuni colpiti dal terremoto del 28 dicembre 1908 o da altri anteriori*). The elaboration of this Royal Decree was also the result of a commission composed of two subcommittees, one of geologists and the other of engineers. Operating on two different levels, the task for the geologists was to identify suitable sites for the reconstruction of the two cities, while that of the engineers was to establish the building criteria to be adopted for the reconstruction, which would then become legislation.[3] [5]

The Royal Decree, thus, firstly reaffirmed the importance of choosing the right location for the *new* cities, taking up a concept already presented in Royal Decree no. 511 of 16th September 1906 (issued as a result of the 1905 earthquake that had hit the same areas of the Strait). In Art.1 it states how different seismic, technical and hygiene aspects, including those relating to the orientation of the buildings had to be taken into account in the rebuilding of the cities. Article 1 in the Decree of 1909, also clearly declares it is forbidden to build on land that is marshy, rugged or subject to landslides or on a steep slope unless it is solid rock, thus renewing the need for a careful choice of where to build. [6]

As regards aspects of building design and construction systems to be adopted in the erection of new buildings, individual solutions were not specified. In accordance with Art. 7 of the regulations, it was however specified that they had to be built using a framework made of wood, iron and reinforced concrete able to resist stress from compression, traction and cutting. The regulations included some characteristic structural types from local tradition, like houses in masonry and the "*casa baraccata*", which was made of stone with an internal structure in wood, whereas it did not consider it appropriate to employ iron and concrete frames when there was a lack of materials or their transportation was very expensive. The building types indicated therefore, were in *ordinary masonry*; those with a *frame* composed of a skeleton of vertical and horizontal elements made of wood, iron or reinforced concrete able to withstand different kinds of stress; and those that were *encaged*, constituted by houses in masonry reinforced with iron struts. [5, 6]

However, it was this legislation that actually promoted the spread of reinforced concrete in the reconstruction of the two cities. In fact, the provision that limited the height of masonry buildings to one floor made it less competitive and favored those in reinforced concrete and reinforced masonry, which instead, gave the opportunity to build two-storey constructions. Seismic legislation, therefore, became an important starting point for defining the dimensional and volumetric data of the new buildings. (Figure 1)

In order to reduce possible oscillations, the height of the reinforced concrete buildings was limited to 10 meters, increased to 16 meters only in some exceptionally justified cases "[…] for reasons of public utility or services, or artistic interest or industrial uses […]".[4] Vaults were prohibited as in many previous regulations, except for those in basements[5], and the use of suspended stairs or those borne by arches or masonry vaults[6]. All projecting or cantilevered constructions were prohibited, except for balconies, cornices and the overhangs of roofs for which the maximum protuberance was fixed at 40 - 60 cm.[7] In Art. 20, an indication was given of the possibility of replacing ordinary roofs, either wholly or in part, flat terraces on a level with the eaves, provided the material used for covering did not exceed 50 kg per m^2. This legislation became fundamental in several aspects of town planning, as it established a special relationship between building height and road width. Specifically, the minimum width of the streets was fixed at 10 meters, reduced to 8 in municipalities with fewer than 5,000 inhabitants, following the favorable opinion of the Civil Engineering Department, and 6 meters if there were buildings only on one side of the road.[8] [6]

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Figure 1. Reggio Calabria, Isolato n. 24, Libretto delle misure, 1929. (Archivio Storico Comunale di RC – Fondo Ente Edilizio, 10. 7. 2, B 25).

It is easy to understand then how these rules determined a type of homogeneity in the urban layout and architecture of the two cities of the Strait in such a way that they were recognized as the very first examples of *earthquake-resistant cities* in Italy. It also meant that the engineers called to delineate the two plans, De Nava for the city of Reggio Calabria and Borzì for Messina, were severely limited in their design.

It is evident that these earthquake standards played an important role, both in directing the designers' choices and in helping to establish, in practical terms, the territorial dimension, morphology and urban space configuration defined by the proportions between the "wide straight" streets and the reduced height of the buildings. [9] [7, 8] (Figures 2-3).

Figure 2. Luigi Borzì, Piano regolatore della città di Messina, 1910, color print on paper. (Archivio di Stato di Me – Fondo Prefettura, B 81).

Figure 3. P. De Nava, Piano regolatore della città di Reggio Calabria, 1914, India ink and pastels on paper. (Archivio di Stato di RC – Archivio Foti, n. 10)

The image of Reggio and Messina after the earthquake, today unfortunately altered by constant substitutions and elevations, was that of two cities crossed by wide straight roads with open spaces, whose width and spaciousness was in effect enhanced by the uniformly low height of the blocks. Within this new spatial concept, the block became the main constituent element of the urban structure[10]. In fact, according to the provisions given in the “building regulations” of the two cities, almost all blocks: were to have the same dimension and quadrangular shape, repeatable *ad infinitum*; they also had to coincide with the lots demarcated by the streets; they had to maintain a height of 10 meters and could not have overhangs or protruberances. The result of these stringent requirements determined an urban structure without hierarchies, where each block was an independent element, in other words, an element devoid of functional and architectural dialogue with the urban context, capable of generating a uniform periphery that could go in all directions. [11] (Figure 4) [7, 9]

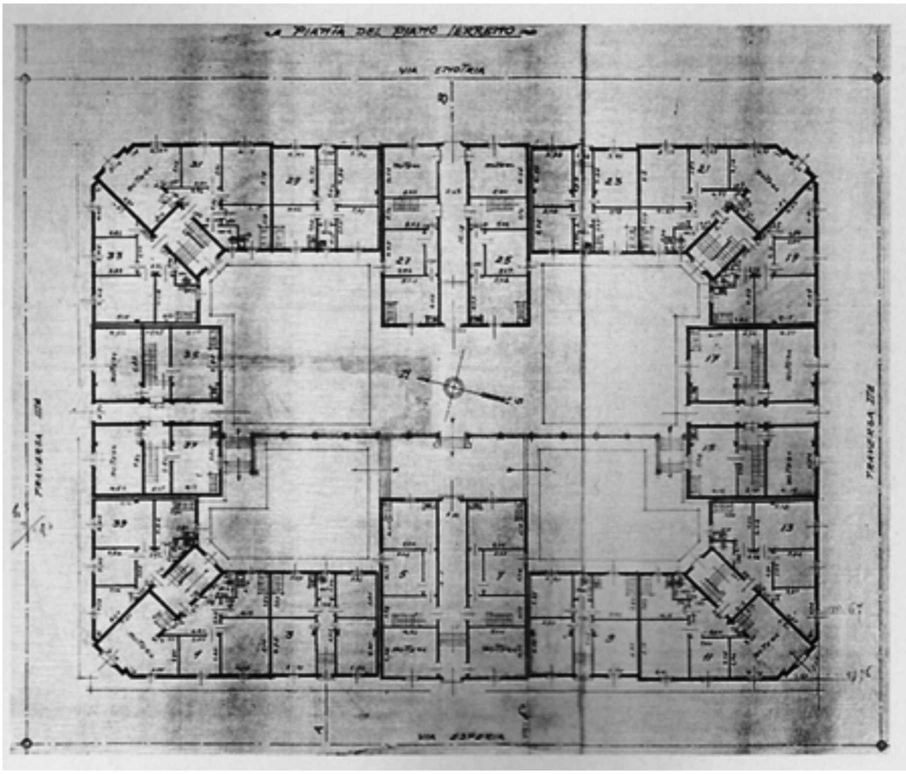


Figure 4. Reggio Calabria, isolato n. 24, pianta del piano terreno, 1929, India ink on paper. (Archivio Storico Comunale di RC – Fondo Ente Edilizio, 10. 7. 2, B 25).

To be fair however, it should be remembered that, in the planimetric definition of the two cities, special attention was paid to the urban tradition of the late nineteenth century, with the classic morphological division in blocks forming a chessboard pattern and reflecting the culture of health and hygiene which almost certainly belonged to Pietro De Nava and Luigi Borzì. The themes of spaciousness, sunlight and ventilation, obtained through a rational and schematic structure of the roads, here became the cornerstones for the new idea of the city. The elimination of unhealthy, disorderly and overcrowded areas was embodied in a city divided into regular blocks separated by a reticular system of roads.[12] [3]

As in the urban mesh of many redesigned cities in the second half of the nineteenth century, such as Cesare Beruto's Milan, reorganized with the master plan developed between 1883 and 1884, here too, the block became the main matrix of city building. It was capable of determining greater control of the areas to be built, through the realization of built environments defined in negative (compared to the 'positive' of public spaces, such as squares or green areas) and constituted by everything that was between the roads. [10-12] In the case of the two cities of the Strait, however, the new urban grid, with its alternating solids and voids, was tightly bound to the technical anti-seismic standards, resulting in a form of *urbis* that was really original for the time.

Although the urban spaces may have been seen as monotonous, it seems that, in Reggio Calabria and Messina, a very simple ‘open’ cultural model was applied, such as that described above, which created the conditions for a very distinctive urban morphology. Paradoxically, therefore, with their extreme simplicity, the technical rules of De Nava and Borzì’s urban development plan, together with the criteria for its implementation gave these cities uniform characteristics in their volumes, in the relationship between the buildings, between the solid and the void, establishing for the time an entirely original spatial image.[13] [7, 13]

That said, to have a complete idea of their reconstruction, in my opinion, another question that was mentioned at the beginning of my discussion should be considered, namely, which construction technique was seen as being the most suitable for building in areas with seismic risk. In this regard, the role of reinforced concrete in the reconstruction of the two cities was fundamental. Studies of reinforced concrete constructions had already been conducted for the earthquake of 1905. One example is that of Mario Baratta, who accurately described some types of houses in a famous little book entitled *The new buildings in Calabria after the disastrous earthquake of 8 September 1905*[14], but it was mainly the earthquake of 1908 and the need to provide immediate answers to the problem of reconstructing the areas destroyed by the disaster, that resulted in the experimentation of this new construction technique through the specific sector of *anti-seismic engineering*. [14,15]

In the first decade of the twentieth century, the theme of the *earthquake-resistant house* becomes a field of investigation both for the technical testing and assessment of the new material, as well as for the free exercise of various formal fantasies that drew inspiration from the structural possibilities offered by reinforced concrete. (Figure 5)

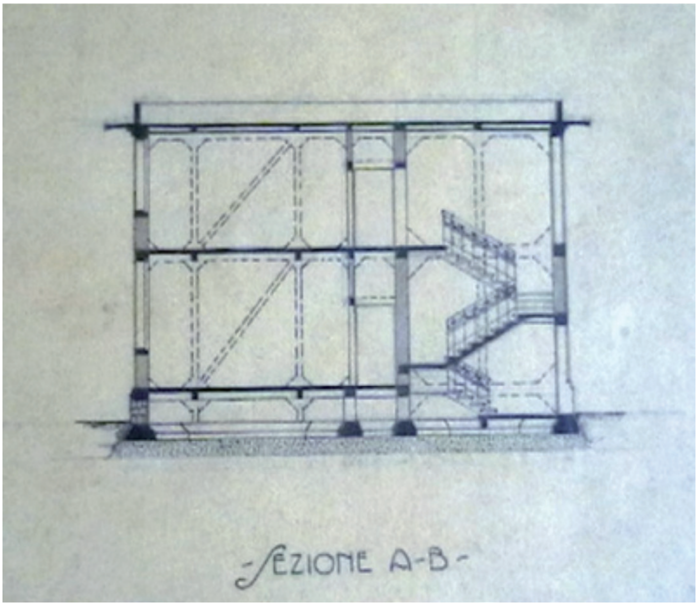


Figure 5. Attilio Muggia, Prog. n. 1883, Villino antisismico con ossatura in cemento armato, 1916, India ink on paper. (Archivio Storico dell’Ordine degli Architetti di Bologna – cart. 3/23, H XXIX, D V bis)

It was even identified as being responsible for a real revolution in building history because, as recalled by Daniele Donghi in the *Introduction* to his famous *Architect's Manual*, "[…] it could replace a variety of constructive elements and so create a new kind of architecture, as happened with iron […]". [16]

Reinforced concrete, the protagonist of the beginning of the last century, became *the* construction technique to use to build the perfect earthquake-resistant house, and sometimes included quite daring projects. Among them, the project for the "city of round houses" that Giuseppe Torres had hypothesized for the new Messina, or the much more feasible project of the *maison-domino* by Le Corbusier. [15]

But it is Daniele Donghi, with the previously mentioned *Architect's Manual* who, in the Appendix, devotes an entire chapter to building safety entitled "*Sicurezza contro lo sfasciamento e la rovina dei fabbricati*", in which he describes the aseismic qualities of reinforced concrete. Further study of the seismic problem resumes some studies previously conducted by the same author on behalf of the "*Comitato Veneto-Trentino Pro Calabria e Sicilia*", formed immediately after the earthquake of 1908. In these studies, Donghi argues as follows that:

"[…] reinforced cement concrete was the best known material for building houses that were monolithic, undeformable and elastic, requirements for countries at risk of earthquakes and additionally with the advantage of being indestructible and non-inflammable […]".[16]

Afterwards, in the work *Organi di difesa e sistemi di ricostruzione*, published in Venice in 1909, Donghi reiterates the importance of reinforced concrete in the concept of the earthquake-resistant home, when he writes that:

"a) to withstand earthquakes, buildings should have a homogeneous, monolithic, elastic and non-deformable structure;
b) structures built with only timber and those in which the timber is responsible for resistance, should be avoided;
c) structures cast in reinforced concrete (*siderocemento*) are the safest. Everyone is in accordance with these conclusions […]."[17][17]

With the same propagandistic intent, he describes the highly innovative characteristics of this building material, claiming that it represented the best that could be found for the construction of indestructible buildings, declaring that "[…] it is known that structures in reinforced concrete are made of cast cement with metal, combined in such a way that the metal and cement bear the strain to which each is best suited, namely, tensile stress and secondly, compressive stress[…]".[18] [16]

Donghi proposed different types of earthquake-resistant houses built with reinforced concrete pillars, platbands, floors, roofs and concrete foundations. According to the author, this "cage" of reinforced concrete made it possible to construct buildings with two or three floors, making them earthquake-proof. He states that "all that is needed is for the foundations to be well-calculated with respect to the ground, the building to be well-anchored to it and for the floors and roofs to divide the strain evenly on the pillars and platbands".[19]

In addition, the results of an international competition, launched in 1909 by the "*Società cooperativa lombarda di opere pubbliche*", aimed at identifying the most suitable building method for reconstruction, officially approved the primacy of reinforced concrete over other construction techniques. It was Arturo Danusso, who was awarded the highest prize. Danusso, who had trained with the Engineering Company, Porcheddu, one of the most important Italian construction companies to operate with reinforced concrete, presented a written statement. In the statement, he argued that the solution to the seismic problem was not to be found in a massive and overly rigid structure, but in a lightweight structure able to gently oscillate during the quake without causing any detachment.[20] According to Danusso, only a reinforced concrete framework was able to ensure all of these elements.[2]

Among the aseismic structures envisaged for the reconstruction, the most recommended construction technique involved the use of reinforced concrete frameworks. However, as mentioned above, in the construction of the post-earthquake buildings of the two cities of the Strait, the presence of anti-seismic regulations were strongly restrictive. So, for normative requirements, the design of the framework of beams and pillars in the reinforced concrete presented small equally spaced spans to facilitate calculations and in addition, infill masonry of the "right" thickness.[21] Therefore, while in the rest of Europe reinforced concrete became more and more synonymous with large spans, daring spaces, large glass windows, in early twentieth century southern Italy, regular rigid structures were used, where the infill masonry played a key role in the volumetric rigidity of the building. [22] [1, 2]

In the prospectus and in the layout, the architectural language followed that of the classical tradition. In fact, in observing the projects of many historic buildings in Reggio and Messina it is immediately evident how the innovative spatial potential connected to the use of reinforced concrete does not particularly influence the design of the buildings in the reconstruction. The spatial setting that predominates is a traditional one, in which the dividing walls, incorporating and hiding the reinforced concrete frames, restrict and fragment the space, forgoing the flexibility and continuity of the environments and the possibility of large openings independent from the load-bearing structures. (Figure 6 a, b) [13, 18]

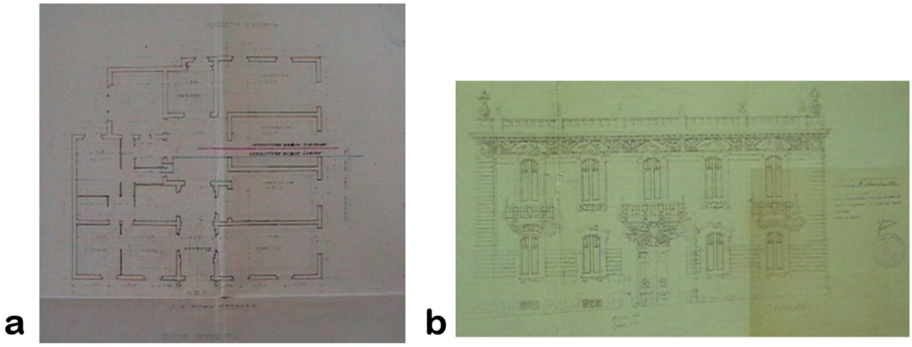


Figure 6. Camillo Autore, Reggio Calabria, Casa Mazzitelli, plan ground floor (a) and the main prospect (b), India ink and pencil on paper (Archivio Storico Comunale di RC – Commissione Edilizia, B 15, fasc. 9).

In the reconstruction of Reggio and Messina, the Hennebique system was the most widely used thanks to the presence of specialized firms that were depositories of the patent; the principal company, located in Turin, was that belonging to the engineer, Porcheddu. The system, in this case, was adapted to the different needs of the place and to the precise legislative requirements. Once again, therefore, the seismic legislation became the primary method of prevention and monitoring used by the municipalities involved.

3. The aseismic architectures of the reconstruction

In the early constructions of Reggio and Messina, many buildings had a framework structure in reinforced concrete that was not limited to the beams and pillars but also included architraves and jambs for the windows which in part reproduced the wooden frame design of the "*baraccata*" house for greater security. Solid bricks were used for the foundations and the ground floor, while for the first floor perforated bricks were adopted. Even the floors were in reinforced concrete, so as to constitute a slab that was resistant but elastic in both directions. Compared to the frame only being in reinforced concrete, therefore, there were substantial differences in design in the buildings of Reggio and Messina of the early twentieth century. This different way of building was termed confined masonry construction (*muratura confinata*). There were three main structural elements that characterized the "*muratura confinata*": the main framework, the secondary frame and the masonry. They were closely related to each other and together, constituted the resistant structure of the building, representing at the same time, the construction technique mostly adopted for many of the Strait's buildings. [8]

In the project reports of many buildings of the reconstruction, in fact, it is not uncommon to find the words "brick masonry with reinforced concrete cage"[23]. So, for example, in the project of the Prefecture of Reggio Calabria, realized by the engineer Gino Zani, it was specified that the main framework, containing special iron reinforcement composed of rods connected to each other by spiral coils, included the basic frames of the bond-beams and those at the top, the intersection of the upright posts of the walls and partitions, and those needed for the completion of the vertical frames. The secondary framework, instead, included all the ribs, both vertical and horizontal, that had to maintain the masonry work inside the meshes of the main framework, in other words it had "to confine" the masonry. More specifically, therefore, it was the main framework that had to resist seismic stresses, while the secondary framework, connected to the main frame, was used to 'stiffen' it and give more stability. The aim of the latter, moreover, was to "[…] enclose, animate and consolidate the masonry work itself; to connect it to the main upright elements and pre-stressed concrete beams and to frame the doorways and windows […]".[24] [19]

The construction technique of confined masonry building, still very much in use during the '50s, is a clear demonstration of how, in the areas of reconstruction, different construction systems were used alongside the single reinforced concrete frame. Among the proposed solutions for the construction in the field of experimentation in reinforced concrete, those to be remembered are those of the engineer, Gino Zani (1882-1964) for the city of Reggio Calabria; especially for the originality of the building system used, based mainly on the prefabrication of the different structural elements.

Gino Zani was a key figure in the post-earthquake reconstruction of Reggio Calabria. His architecture, in fact, was a distinctive and original element in the urban reconstruction of the city. It represented the most modern that Reggio was able to conceive for its rebirth. His obstinacy in the choice of his designs and his technical background allowed him to carry out the reconstruction of many parts of the city in a short time, becoming a skilled architect and a talented urban planner; as well as one of the precursors of modern earthquake-resistant constructions and prefabrication systems. For the city of Reggio, he was a sort of pioneer in the use of reinforced concrete. (Figure 7) [8]

It was in the reconstruction of the city, that he noted the disadvantages of the construction systems employed until then. He therefore proposed, among other structural innovations, the use of concrete blocks of various types, but "[…] all based on one type, so that they could be produced from one formwork simply by moving the internal cores to form holes and recesses, arranging the metal reinforcement horizontally and vertically inside the holes in the blocks and filling them with a concrete mix […]". [25]

Overly convinced that a proper earthquake-resistant house could only be achieved through the adoption of lightweight structures in reinforced concrete adequately blocked at the base, the engineer from San Marino at a ministerial meeting in 1912, convinced those present of the positive qualities of his earthquake-resistant house in reinforced concrete, described by Zani himself as follows:

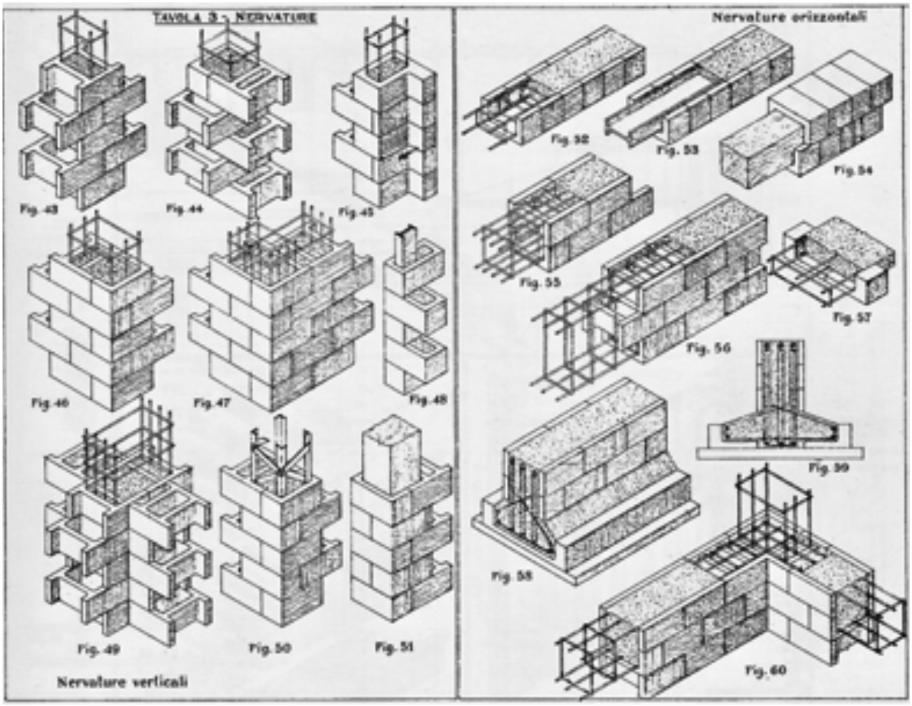


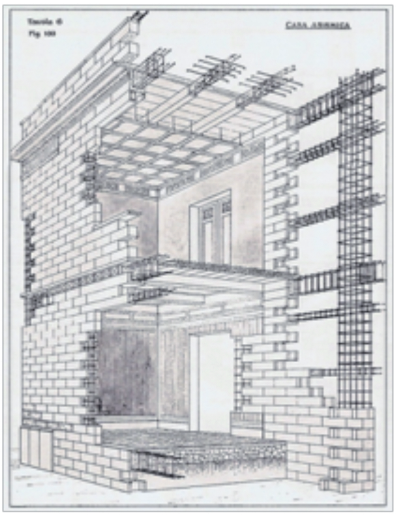
Figure 7. Gino Zani, Tavola 3 – Nervature (ribs) (LO CURZIO 1986)

"[…] I imagine my aseismic house like a boat that is able to dance on the waves without breaking up […] able to prevent the cracks in the ground from being transmitted to the walls and to minimize the effects of the undulatory movements […]"[26]

Zani's constructional solutions were numerous and were repeatedly revised and improved; the documents can still be found today in the Municipal Historical Archives of the city of Reggio Calabria.[27] They include various types of wall structures, simple and reinforced, superimposed on a skeleton made of reinforced concrete or free-standing; architraves with prefabricated elements instead of the usual wooden beam to accommodate the reinforcement and subsequent concrete casting; parapets anchored to horizontal structures with beams or walls; coping to anchor the roofs, so as to avoid any pressure; provision and reinforcement of bond-beams; stairs with beams and buttressed foundations; reinforced steps with bracket supports; floors with parallel and crossed ribbing, either partially prefabricated or entirely cast *in situ*, with slim hollow bricks and hollow blocks provided with reinforced links with ceilings in expanded sheet metal to form an air chamber or with the use of pumice of Lipari to obtain the necessary thermal and acoustic insulation. [1, 8]

As previously mentioned, the most striking aspect of the rich and varied production of Gino Zani is the special attention given to the design of prefabricated aseismic structures. For instance, the prefabricated elements used to obtain beams and pillars, which were completed with additional reinforcement and concrete casts, especially at the junctions, enabled aseismic frames of considerable rigidity to be made and at the same time eliminated the use of formworks. Another example involved reinforced concrete floor slabs with parallel ribbing produced using metal formworks that made it quick and easy to cast and then dismantle. [28]

The houses built during the years of expansion in the north and south of the city of Reggio, especially in the districts of St. Lucia, Mussolini, Mezzacapo and Gabelle, had this kind of reinforced concrete structure. It was made up of primary and secondary upright posts, with a stringcourse frame in correspondence with the paving of the raised floor, eave framing and bond-beams and architectural elements for dividing spaces. The floors were made of reinforced concrete slabs with ribs; full bricks were used for the outside walls of the ground floor and in the interior walls facing the stairs, while hollow bricks were used for the exterior and interior walls of the top floors. The foundations were of masonry stones and semi-hydraulic mortar, and the base frame in reinforced concrete rested directly on top. Finally the terrace coverings, typical of Mediterranean constructions, were constituted by an inclined slab covered with a layer of asphalt overlaid with concrete tiles. [29] (Figure 8 a, b) [20]



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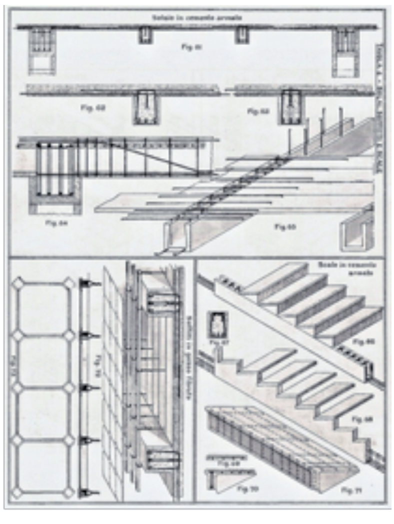

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Figure 8. Gino Zani, Tavola 6 – Casa asismica; Tavola 4 - Solai, Soffitti e Scale. (LO CURZIO 1986)

Over the years, other sophisticated tests involving the framework structure and also the type of reinforcement to be adopted in the areas of the Strait were envisaged. One of them proposed a very expensive solution which was however immediately abandoned. It consisted of a latticed metal framework, created by riveting with L profiles and flat profiles; it was subsequently embedded in a cast of cement mix in order to achieve a highly reinforced concrete structure. Other structures were also adopted using reinforced concrete, they did not however use a framework structure. This was the case of the patented system produced by the *Società Vianini*[30], which provided for the construction of the building through the aggregation of independent blocks, each comprising one or two rooms, connected externally only to ensure continuity of prospects and internally for communication between the rooms. Each block was substantially monolithic, with its own foundation which was capable of fluctuating without affecting adjacent elements. The system, however, failed to spread, while the reinforced concrete frame, with simplified reinforcement, continued to gain ground, spreading rapidly also in those areas not affected by seismic risk. [2]

As regards the new construction technique, however, there was some concern from academic circles which advocated the use of reinforced concrete only for certain parts of the building, in particular, the foundations that were to be "grade slab". All this gave rise to a real debate on the use of reinforced concrete, testified by the numerous articles that appeared in magazines and newspapers of the towns affected by the reconstruction at the time. In the "*Gazzetta di Messina e delle Calabrie*" of 5-6 May 1910[31], for example, a polemical article involving the engineer Giunta versus the engineer Giovanni Salemi Pace was published on the use of reinforced concrete in the earthquake-resistant buildings of Reggio and Messina. As a member of the commission for the study of building standards to be adopted for the municipalities interested by the earthquake, Salemi had proposed, as the best preventive method, the use of reinforced concrete frames; in this regard he had been criticized by Giunta, who was inclined to use a mixed system of reinforced concrete and masonry. The argument was therefore full of conflicting theories. In many texts and treatises of the period, in fact, the use of a reinforced concrete frame for the construction of the buildings of the Strait was still the most recommended system. [21]

Beyond the recommended construction systems, however, many of the buildings in earthquake areas are the result of conditions imposed by seismic legislations enacted after the earthquake of 1908. In the city of Reggio Calabria, starting from 1924 and until 1935, it emerges how through legislative decrees precise provisions are given both for the size of the buildings and for the construction of the walls.

These laws concerned technical and hygiene aspects for the areas hit by the earthquake of 1908 ("*Norme tecniche ed igieniche per le località colpite dal terremoto del 1908*") issued in the years: 1909 (Royal Decree (R.D.) 18 April 1909, n. 193), 1913 Consolidated law approved with Legislative Decree 19 August 1913), 1924 (R.D. 23 October 1924, n. 2089), 1927 (R.D. 13 March 1927, n. 431) and 1935 (R.D. 25 March 1935, n. 640). They gave rise to the construction of many earthquake-resistant buildings in Reggio in the first decades of the twentieth century, in which the mixed structure and that in reinforced concrete were just some of the possibilities envisaged, although later these would become the most widespread. In 1911, for the construction of aseismic houses in Reggio and its province, for example, one company, the Società *Anonima Cooperativa di costruzioni edilizie nella Provincia di Reggio Calabria*, in agreement with another, the *Cooperativa Lombarda di LL.PP.*, proposed the following building systems:

"[...] a) Constructions of timber frame with suitable and robust iron joints and mesh filled with light material and inner tube, and light-weight covering in Marseille or Eternit tiles. The timber must be of excellent quality and strong essence such as larch, pine, with special seismic foundations. b) Constructions with mixed frame for economic and rustic houses with hollow concrete blocks, metal reinforcements arranged in hollow vertical columns and horizontal joints; mesh filled with interlocking hollow blocks, partitions in concrete with a core of wire mesh or sheet metal, terrace roofing or Marseille tiles. Special anti-seismic foundations. c) Civil constructions and buildings with reinforced concrete framework strengthened using platband profiles placed close to parabolic profiles and mesh filled with light-weight masonry, connected by metal rods passing through the masonry vertically and horizontally and connecting to the reinforced structure itself. Terrace roofing with air chamber, waterproof hood, tiled flooring or roofing in Marseille or Eternit tiles. Special anti-seismic foundations in grade slab reinforced with concrete beams. d) Buildings with metal frameworks, exterior walls in light-weight material, secured by metal mesh covered with cement plaster, including partitions with a steel frame in sheet metal or light masonry with special reinforcement and anti-seismic foundations […]".[32][22]

Once the most suitable building system had been chosen by the clients according to their needs, the project was drawn up observing all the technical and hygienic provisions required by the building code of the municipality concerned. In addition, in a scale of 1 to 10, it was necessary to include detailed drawings of all the ribs, foundations, struts, chords, frames for openings, slabs for floors and roofs; quantities of the materials to be used, their quality and origin and test loads. In particular, for constructions in reinforced concrete, it was obligatory to respect the regulations containing the ministerial standards of 17 April 1907.[33]

4. Final considerations about the post-earthquake reconstruction

The reconstruction of Reggio Calabria and Messina was a huge urban planning operation of building design and experimentation as had never happened before in Italy. Its ultimate goal was to protect the sites in question from a future earthquake disaster, without forgetting the possibility, tragically provided by nature, of making these two cities, reconstructed *ex novo*, a tangible example of early twentieth century urban concepts. It was an example in which urban design, in harmony with architectural design, became an indispensable starting point for the redefinition of a city that had been reduced to rubble by an earthquake and where planning efforts easily shifted from designing buildings, streets, squares, stairways and gardens, to designing kiosks, benches, lamp-posts, fences and gates.

Architects such as Camillo Autore, Ernesto Basile, Marcello Piacentini worked carefully to redefine the new image that Reggio and Messina was to have, repeatedly interpreting the poetics of the neoclassical and modernist style. In reality, however, the modernist movement, which during the twenty years of the Fascist regime, should have led to a formal renewal of the buildings, in this case, appeared to be an illusion[34]. Even if simplified, the architectural language remained that of the classical tradition in which, both the exterior and the interior of the building itself remained untouched by the formal innovations related to the advent of reinforced concrete. The organization of the interior spaces and the articulation of the facade recalled the compositional scheme of Renaissance buildings and consequently followed its architectural canons. [23, 24]

Thus, for example, the appearance of the most representative public buildings referred to a single compositional layout consisting of a slightly protruding central body, generally tripartite with two symmetrical wings characterized by a succession of identical elements, and corner solutions, which were also symmetrical, protruding and often defined by pilasters.[35] Even private buildings were affected by the compromise between the stereotypes of the past and the new earthquake regulations adopted after the earthquake. In the small private buildings of Reggio Calabria, for example, the nineteenth-century layout and the Renaissance language coexisted, without trouble, with the modest views. The stone ashlars and fake ashlars blended with the brick and the 'hammered' plastering. Double lancet and triple lancet windows with architraves alternated rhythmically on the side view of the different floors, and the portal characterized by two columns supporting a "short protruding balcony", in accordance with the city's building code. [36]

It seemed an illusory desire to re-establish, through architecture, a historical order that had abruptly been eliminated by the unexpected strength of nature. "New" cities, therefore, were built with stylistic references that, on the one hand, testified to a desire to build a sometimes overly lavish, fictitious past and, on the other hand, appeared to be influenced by the architectural historicism in vogue at the time. The weight of history and the reassuring use of tradition prevailed over the formal and stylistic innovations related to the use of reinforced concrete. It was a return to the architectural canons of the past in order to rebuild not only a city but also the historical memory of a people whose cultural identity had been so hard hit.

5. Appendix: Short notes on today's preventive methods

The sad news of the earthquake of 24 August 2016, with epicenters in the provinces of Rieti, Ascoli Piceno and Perugia, tragically reminds us that Italy is a territory of high seismic risk. The news from the places of the disaster depict an area lacking the most basic anti-seismic measures necessary for the safeguard of the town, both in the case of old towns without seismic adaptations and in the not 'up to standard' construction of new buildings. This sad story, consequently invites us to make some additional considerations about today's preventive methods.

Nowadays, in Italy, seismic safety is achieved through the use of two important tools: seismic regulations which, as seen, establish the criteria by which to build in areas subject to seismic risk and seismic classification which catalogues the territory according to the seismic hazard in the different geographical areas. In Italy, from 1908 until 1974, it was only after the occurrence of telluric events that municipalities were classified "at risk of earthquake" and therefore submitted to restrictive building regulations. However, with the enactment of Law n.64 of 2 February in 1974, it was established that seismic classification had to be based on proven technical-scientific grounds and applied to the whole territory of Italy.

Between 1981 and 1984, through criteria drawn up by the CNR, special ministerial decrees were issued, that ensured the classification of about 45% of the territory under examination. More than half of the territory, however, remained unclassified. Only after the earthquake of 2002 that struck Puglia and Molise was it decided to act decisively to complete the task. Through the Order of the President of the Ministers Council, no. 3274 of 2003, reclassification of the entire national territory was established in four different hazard levels. This represented an important turning point for Italy, because it highlighted, definitively, that no area of the country could be considered unaffected by the earthquake problem. The classification in question goes from grade 4 (gray areas) attesting to minimum risk, up to grade 1 (red zones) representing the highest level of danger; but starting from level 3 and up to level 1, aseismic planning was to be considered mandatory.

Improvement in territorial monitoring, over the years, has been accompanied by equivalent improvement in the law. The anti-seismic standards currently in force in Italian legislation date back to 2008; they are stated in the Ministerial Decree of January 14, published in the Official Gazette n.29 of 4 February 2008 - Ordinary Supplement n.30. These new technical standards, describing in more detail the aspects set down by *Eurocode8* for construction in seismic areas, became mandatory from 1 July 2009 onwards, following the enactment of Law n.77 of 24 June 2009.

The Decree of 2008 is extremely important because it defines the principles for planning, building and testing all earthquake-resistant buildings, at the same time, guaranteeing that an accurate assessment is made of the static nature of public buildings (considered “strategic buildings”), such as schools, hospitals, churches, museums, bridges, etc. In the building design it indicates the minimum size of the pillars and load-bearing walls and accurately defines architectural limits. Specifically, the layout of the buildings must be regular and symmetrical, whereas the maximum height of the building depends on the seismic classification of the territory: houses that fall in zone 1, for example, must not exceed two floors in height.

Therefore, when planning to build in a seismic zone, there are several things to keep in mind, including of course the material to be adopted in constructions considered “safe”. Among the recommended aseismic materials we find reinforced concrete either normal or pre-stressed, wood, steel and reinforced masonry. In constructing with reinforced concrete the following points are defined: the minimum diameter of the steel bars to be used for reinforcement (5 millimeters); the strength of the cement, which varies from area to area depending on the seismic risk (class 8/10 is the minimum, class 90/105 is the maximum); and the amount of steel to be used in proportion to the cement, the so-called reinforcement of pillars and beams. If properly assembled with mechanical joints, wood is also an excellent material for building earthquake-resistant houses due to its characteristics of great flexibility and strength. Its history as an aseismic material goes back in time to the “*casa baraccata*”, used by the Bourbon Government after the earthquake of 1789 in Calabria and the “*gaiola pombalina*” of the famous Marques de Pombal, used in Lisbon after the disastrous earthquake that destroyed the city in 1755. Steel structures are also particularly suited to withstand earthquakes due to the ductile property of the material and its high flexibility and lightness. In fact, if one starts from the premise that earthquake forces are associated to inertia and thus connected to the mass of the structure, we can understand how, by reducing the mass, it automatically reduces the seismic forces in the design. This explains why, in past earthquakes these structures have been shown to perform much better than those built with heavier materials. Finally, the construction system of “reinforced masonry” is also recommended because it is the natural evolution of the load-bearing masonry structures used for zones at greater risk of earthquakes and, if properly constructed, is considerably more ductile, behaving in a similar way to structures, such as dividing walls, in reinforced concrete.

In the planning phase, the structure's resistance to a whole series of stresses is obtained by applying the calculation rules described in detail in the law. An anti-seismic building, in particular, must be able to resist torsion, deformation, cutting, bending, vibration, cracking and corrosion. It is also necessary to assess the adhesion of the steel bars to the concrete and, in the case of wooden constructions, the resistance to tensile, bending and compression of the wood fiber itself.

The ultimate aim of the anti-seismic construction is to build a structure that can withstand as much as possible the action of the earthquake, thus delaying the total collapse of the building to save more lives. In addition to practical arrangements related to the correct use of construction techniques, another part of the planning includes other preventive methods to minimize damage. Among them it is worth mentioning, for example, strengthening certain parts such as dividing walls, stairwells, elevator shafts which, if perfectly connected to the rest of the structure, tend to absorb horizontal movements. Good preventive methods also include the careful design of structural nodes (beams-pillars) with appropriate buttresses; the use of chains to increase structural resistance; the adoption of seismic vibration dampers in the vicinity of the structural joints; or implementing the criterion of "the hierarchy of resistances" that envisages the design of a structure in which the plastic hinges that generate the collapse is formed first in the beams, then in the pillars, so as to delay the general collapse of the building. [25, 26]

Currently, there is a tendency to replace the traditional frame in reinforced concrete, consisting of pillars and beams, with a structure of internal and external deep beams with different orientations linked directly with the flat slabs. There are also recent studies based on the possibility of building structures capable of modifying their structural elasticity in relation to the seismic shock that strikes them. Known as seismic isolation, it became established especially after the Kobe earthquake of 1995. The new seismic method consists in putting a horizontally deformable device between the ground and the supporting base of the structure. The device is called a *seismic isolator* which, in most cases, is made from layers of high bearing capacity rubber alternated with layers of steel plate bonded together; these are interrupted centrally by a damper, which generally consists of a ductile metal. Used mainly for the construction of public buildings, such as schools, this system is not applicable to very high buildings or when the supporting soil is very soft. In this case, instead of insulating the foundations, structures can be designed with a ductility capable of dissipating plastically the energy transmitted to the construction by the earthquake. Energy dissipation must take place in strategic points, planned in the design phase, so that they are able to withstand large displacements. [27, 28]

The superiority of structures with seismic isolation systems compared to those with fixed base systems, is motivated by the fundamentally diverse oscillation period. In fact, while the frequencies of structures in reinforced concrete with fixed base coincide with the majority of earthquake frequencies which, through the phenomenon of resonance in the elastic range, lead to the amplification of the shock effects, in structures equipped with "seismic isolation" it is possible to design an isolated structure with a much lower frequency than that of earthquakes. The result is a much more resistant structure, because it significantly reduces the horizontal forces transmitted by the earthquake to the building. Seismic protection of this kind is therefore of a high level and greatly limits overall damage. [29]

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Notes

[1] For details, see: SIMONE, *La città di Messina tra norma e forma*, Roma, Gangemi editore, 1996, p. 111.
[2] Cf. BARUCCI, *La casa antisismica: prototipi e brevetti; materiali per una storia delle tecniche e del cantiere*. Roma, Gangemi, 1990, pp. 165-167.
[3] Ibid.
[4] *Norme tecniche ed igieniche obbligatorie per le riparazioni, ricostruzioni e nuove costruzioni degli edifici pubblici e privati nei Comuni colpiti dal terremoto del 28 dicembre 1908 o da altri anteriori*, R.D. 18 aprile 1909, n. 193, art. 3 (Published in the Gazzetta Ufficiale n. 95, 22 April 1909).
[5] *Norme tecniche ed igieniche obbligatorie*..., cit., art. 10.
[6] *Norme tecniche ed igieniche obbligatorie*..., cit., art. 16.
[7] *Norme tecniche ed igieniche obbligatorie*..., cit., art. 18.
[8] *Norme tecniche ed igieniche obbligatorie*..., cit., art. 22.
[9] Cf. FERA, *La città antisismica: storia, strumenti e prospettive della pianificazione territoriale per la riduzione del rischio sismico*. Roma, Gangemi, 1991, p. 94.
[10] For details, see: COLISTRA, *Reggio Calabria: l'architettura e la città. (Collana del Dipartimento di architettura e analisi della città mediterranea. Quaderni della ricerca)*, Jason stampa, 1999, in particular the chapter entitled "Gli elementi dell'architettura".
[11] Cf. COLISTRA, *Reggio Calabria: l'architettura e la città*…, op. cit.
[12] Cf. SIMONE, *La città di Messina tra norma e forma*, Roma, Gangemi editore, 1996, p. 71.
[13] Cf. FERA, *La città antisismica: storia, strumenti*…, op. cit., pp. 100-101.
[14] Analyzing several kinds of houses designed by the engineer Accusani for the town of Favelloni, Baratta described the aseismic typologies adopted : "[…] The houses adopt a construction system in reinforced concrete constituted by a vertical pillar structure with horizontal beams and girders, so as to form a frame in rigid béton, then closed with thin walls and slabs of the same material [...]. The openings between the vertical reinforcement, the base frame and the overlying horizontal beams are closed by masonry made with small parallelepiped blocks with double holes, produced with pumice concrete and joined together using cement mortar; air circulates in the holes which serves as insulation [...]. The partitions, of variable thickness are also built with small blocks [...]. Some of these rectangular blocks, for greater security, are reinforced section by section with vertical round rods and cement […]." Cf. BARATTA, *Le nuove costruzioni in Calabria dopo il disastroso terremoto dell'8 settembre 1905*, Modena, Società Tipografica Modenese, 1908, pp. 80-83.
[15] In reality, there is no trace of the two cities in the projects of Le Corbusier and Torres this is because, once again the use of reinforced concrete is strongly restricted due to the presence of aseismic legislation that limited the formal freedom of the designers by imposing a rigid approach in the design of the buildings.
[16] DONGHI, *Manuale dell'architetto*, Appendix , p. 145.
[17] DONGHI, *Organi di difesa e sistemi di ricostruzione*, Venezia 1909, pp. 18-19.
[18] This is a highly advantageous combination compared to non-reinforced concrete monoliths, because, as they have the same resistance, the dimensions of the reinforced concrete are much smaller than those of the simple concrete and because the composition of this material has a higher degree of elasticity than the limited elasticity of simple concrete. DONGHI, *Manuale*…, op. cit. pp. 35-37.

[19] Ibid.
[20] In the text, the engineer also speaks of the dynamics of the structures, in which he physically establishes the relationship between the resistance of a building, its mass and its flexibility. See: DANUSSO, *La statica delle costruzioni antisismiche*, in " Il Monitore Tecnico", 33, 1909, pp. 641-645.
[21] For details, see: IORI, *Il cemento armato in Italia: dalle origini alla seconda guerra mondiale*. Roma, Edilstampa, 2001.
[22] Cf. IORI, *Il cemento armato in Italia*…, op. cit. For more details on the concrete story, see: SIMONNET, *Le bèton: histoire d'un materiaux: économie, technique, architecture*. Marseille, Ed. Parenthèses, 2005.
[23] *Corpo Reale del Genio Civile, Edificio per la sede della R. Prefettura di Reggio Cal., Capitolato speciale d'appalto*. Roma, Cooperativa Tipografica Manunzio, 1914, pp. 19-20.
[24] Ibid.
[25] Cf. LO CURZIO, *L'architettura di Gino Zani per la ricostruzione di Reggio Calabria*. Gangemi, 1986, p. 17.
[26] Ibid.
[27] Cf. LICORDARI, *L'utilizzo del cemento armato nella ricostruzione delle città dello Stretto dopo il terremoto del 1908*. Roma, Aracne Editrice, 2016.
[28] LO CURZIO, *L'architettura di Gino Zani*…, op. cit., p. 28.
[29] Cf. *Ente Edilizio di Reggio Calabria, Ufficio Tecnico, Progetto per la costruzione di case economiche, relazione descrittiva*. Reggio Calabria, 18 dicembre 1927. (ASRC, 10.8.3 , B 103).
[30] Patent n. 100064, G.Vianini & C.; see IORI, op. cit, Note p. 105.
[31] GIUNTA, *Discussione libera in tema di costruzioni*, in "Gazzetta di Messina e delle Calabrie", 5-6 Maggio 1910.
[32] *Convenzione tra la Cooperativa Lombarda di LL.PP. e la Cooperativa di costruzioni edilizie nella Provincia di Reggio Calabria*. Reggio Calabria, 1911, pp. 2-3. (ASRC, D.P. B11/634).
[33] Ibid.
[34] Cf. COLISTRA, *Reggio Calabria: l'architettura e la città*…, op. cit.
[35] Cf. ARICO', MILELLA. *Riedificare contro la storia*. Roma, Reggio Calabria. 1984.
[36] Ibid.

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Biographical notes

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