The Viaduct of Corso Italia in Bari was one of the first realizations in Europe of a superelevated railway using the reinforced concrete technology. Built in 1915, it is an outstanding example for the simplicity and effectiveness of the structural solution. Light and elegant, it is more than one kilometer long, and was built in only eight months by Porcheddu Enterprise, employing the Hennebique patent for the constructive system.

Appreciated as an artwork in its genre by the contemporaries, it is nowadays a significant historical example, showing the high technological and formal level of excellence achieved in the field of concrete construction.

The Viaduct is located in a strategically central area of the city, but unfortunately its immediate surroundings suffer a condition of urban decay. The situation is threatening to get worse, since a plan of general reorganization of the railway junction of the city provides the abandoning of that rail branch.

A question about the structural and functional rehabilitation of this work arises, and the discussion of the case study opens quite a few interesting points of reflection and investigation. In fact, many buildings and constructions belonging to the first decades of the twentieth century are present in our cities, and there is an urgent need of maintenance and rehabilitation for these pieces of work so rich in historical, architectural and cultural significance.

It is nowadays acknowledged that concrete is not an everlasting material. Despite of the fine and accurate quality of the work, this technology is subject to the deteriorating action of time even more than masonry is.

Hence, it is particularly important to study in detail the historical examples, and to recognize the characters and the technical details of the solutions if we wish to keep the trace of the history and preserve the memory of the architectural and structural buildings of the ‘900. In this paper, a hypothesis for the reuse will be presented, and some general problems related to the diagnostics and the rehabilitation of historical R.C. constructions will be discussed.

THE DEVELOPMENT OF RC TECHNOLOGY AND THE HENNEBIQUE PATENT

There is a number of historical antecedents to the reinforced concrete, and indeed concrete in itself has the same ancient and noble roots than masonry and stone constructions. Nevertheless, these precedents had only a negligible influence on the events that marked the end of the Nineteenth century and decided the beginning of a new Age for construction, within that second Industrial Revolution that was disruptively breaking into the world scene. Indeed, the appearance of the reinforced concrete system, unlike the previous building technologies, can be considered to be the fruit of a brilliant «invention» [4, 5] and not the result of a smooth and gradual development.

This is demonstrated also by the proliferation of patented systems: one for all, the one registered by Monsieur Francois Hennebique, whose name will be eternally bound to the development and diffusion of the new material. He himself contributed, in a certain sense,
to create the myth of the Ingenious Inventor, not without a cunning sense of business. The reference is to a popular anecdote according to which the entrepreneur Hennebique, while building a house in Belgium for his client, Mr. Madoux, happened to witness a terrible fire destroying a nearby building. So, he had a brilliant flash of inspiration and thought of a fireproof floor, made with a brand new material: the reinforced concrete. The slogan of the trademark became, in fact: «Plus d’incendies désastreux». Actually, it was the birth of an extraordinary climb to success for the man and the enterprise bringing his name.

More then the originality or the intrinsic superiority of his patent in comparison with the rival firms, the key of success was the great ability in the business strategy (actually, many features of the patent he used to display as personal ideas were present in previous elaborations).

On the one hand, he created a very effective organization, a net of agents and dealerships worldwide spread (by 1908, he had 42 affiliates in Europe, Africa, Asia and America) that can truly be considered an «ante litteram» franchising.

On the other hand, he acted a successful strategy of advertising and diffusion within the technical, academic and political circles. He promoted technical meetings and discussions, conferences (he was the organizer of the first conference on reinforced concrete), invited professionals, academicians and politicians in the building yards, founded a technical journal (Le Béton Armé) on which even used to broadcast some disastrous failures of his rivals. What is certain, is that in the course of a few years (from 1892 to 1909) he realized 20824 projects, among which 1300 bridges. The unbroken success of his works strengthened his fame. As he himself liked to say: «my buildings speak for me».

The calculation method

The design of the structural elements subjected to bending moment is a peculiar feature of the Bureau Hennebique. Even if it was actually incorrect, the successes obtained in the practical application seem to demonstrate the effectiveness of the procedure. By all means, this should be ascribed to the great sensitivity and experience of the inventor, who was able to envisage mechanical phenomena still unknown at that time.

The method was based on the equal sharing out of the work between the concrete and the iron. A half of the bending moment was absorbed by the concrete, and a half by the reinforcements. The position of the neutral axis was an unknown of the problem, to be determined by an equilibrium equation between the half moment and the concrete stress (considered uniformly distributed and equal to 25 kg/cm²). Then, the correspondent equation applied to the steel allowed the determination of the minimum required area (assuming that the steel stress and the distance from the neutral axis is fixed).

The Porcheddu Company

One of the dealerships of Hennebique trademark in Italy, the most representative and important, was the Company G. A. Porcheddu, operating in Italy from 1894 to 1933. Endowed with a modern and efficient organization, this professional office was able to develop autonomously the design activity: it is worth remembering that the Company released a number of original patents, and employed for the first time a light mixed roof made of r.c. and bricks, the forefather of a type that today is the undisputed ruler in the Italian building scene. The company was the protagonist of great and significant projects in Italy. The most renowned is certainly the Bridge Risorgimento on the Tevere River (Rome). It spanned with a single bay a distance of one hundred meters and held the primacy of the longest r.c. bridge for many years.

Mostly present in Piemonte and Northern Italy, some projects were carried out in the rest on the country too, above all in the hard years of the first world war, when it remained the only Italian agent for the Hennebique trademark.

In Southern Italy, there were very few works of the Porcheddu Company, and the only bridge is a railway viaduct located in the city of Bari.

The Viaduct of Corso Italia, Bari

The History

At the beginning of 1915, the opening of a new 1200 kilometers railway line connecting some Italian regions (Puglia, Calabria, and Basilicata) was
announced. The event was really significant under a social, economic and political point of view. In fact, it established, at last, a connection among territories geographically isolated and set apart from the economic scene since that time.

The enterprise was hard, and was the occasion for the realization, in Southern Italy, of a significant example of the rising technology of reinforced concrete. In fact, while other bridges and viaducts of the line were traditional masonry or steel constructions, one of the branches—the 280 km long-line Bari-Atena—started in the city of Bari with a concrete flyover track «just like those built in the big foreign metropolis» (newspaper of the *Touring club Italiano*, N. 1, January 1915 [7]). It was more than one kilometer long, and indeed it was one of the first examples in Europe of a railway line set over a concrete viaduct. Surely, it was the longest in Italy and represented a technological milestone. It brought in Southern Italy that revolution that had invested many European countries and, with the coming of a new modern material, would have radically changed the Structural Design and the Architecture, as well.

**Technical features**

The viaduct was designed and built by the Porcheddu Company, which completed the work in only eight months of restless activity, despite the difficulties and restrictions imposed by the war (fig. 1, 6). The official test of the flyover, 1038.80 meters long, took place on the 23 of July 1915, and was welcomed by the local press as a symbol of the modernity and technical progress.

The essential and simple (but nevertheless elegant) design revealed itself to be successful, both in the static performance and in the formal solution. The project, registered at the National technical Office for constructions in the May of 1912, provided a structural scheme with equal bays about 9 meters long. Every four bays, a joint breaks the continuity of the system, allowing the free thermal expansion of the spans. Moreover, this structural arrangement, tested with excellent results in many different works by the Porcheddu Company, perfectly fits the theoretical model of calculation (fig. 2).

The structural section that sustains the plank (3.40
Figure 2
The structural model adopted for the calculation

meters wide) is made up of two rectangular beams (60 cm wide and 100 cm high, on average) located just under the axis of the rails, and superiorly connected by a thick slab (11.5 cm) in order to guarantee the collaboration and the transversal stiffness (fig. 3). Finally, the system is completed by a protruding slab (that has a slant of 2.5% for a rapid draining of the water) and by two edge beams holding the rail bed.

The vertical support is supplied by couples of columns founded over a concrete plate. The supports are doubled at the dilatation joints (fig. 4) although founded over the same plate.

All the design was performed in accordance with the in-force law (the Regio Decreto issued in 1907). The work of the materials was kept under the limits prescribed by the law, that is to say, a limit stress of 1000 kg/cm² for the tension in the steel (800 kg/cm² for the shear) and 40 kg/cm² for the compressed concrete (threshold attained, moreover, only in one case), that was made with a measure of 300 Kg of cement for each cube meter of mixture.

Figure 3
Section of the Viaduct; detail of the reinforcements and brackets [6]
From the review of the original project [1], it can be seen that all the calculations were made in accordance to the current methods (indeed, not very far from the admissible stress method that is still used in Italy nowadays), as required by the law. In particular, a 4-bays scheme (fig. 2) was adopted. The dead load was estimated as $4900 \text{ Kg/m}$ (including the structural load and the roadbed), while for the live-loads two typical trains were considered, distinguishing a flexural action from a shear one and obtaining an equivalent distributed load ($6820 \text{ Kg/m}$ and $7500 \text{ Kg/m}$ respectively).

In order to account for the dynamic effects induced by mobile loads, a 25% increment was applied to the mentioned loads, leading to the design values of $8525 \text{ Kg/m}$ and $9375 \text{ Kg/m}$. The maximum bending moment and maximum shear were found from the Winkler tables, for a continuous beam of equal bays, on five supports.

In the static verification, two main beams were considered, having a rectangular section of $60 \times 100 \div 120 \text{ cm}$. The connecting slab was considered to be collaborating for a width of $270 \text{ cm}$.

Considering that the prescriptive value for the homogenization coefficient $n$ was 10, and applying the standard calculation for the design and verification of the section, it can be seen that a minimum quantity of steel of about $150 \text{ cm}^2$ and an approximate height of $110 \text{ cm}$ are required. Actually, in each main beam $4 \Phi 30$ straight bars were adopted, and 5 additional bent bars (Φ 35) were arranged in order to help the maximum stress zones (total amount: $152.76 \text{ cm}^2$). With these entries, the position of the neutral axis results to be at $30.72 \text{ cm}$ from the superior border; the stress ratio is $37.8 \text{ Kg/cm}^2$ for the concrete and $802 \text{ Kg/cm}^2$ for the steel.

The Role of the Patented System after the regulations issuing

At the beginning of the century, the first national technical laws were issued, under the boost of
numerous collapses. So, the end of the age of the pioneers of concrete arrived, and a field until then characterized by the personal undertaking and ability in conquering the market was finally reorganized. Many European countries soon adopted rules for the concrete constructions (1903, Switzerland, 1904 Germany, 1906 France).

In Italy, the regulation arrived in 1907, and even if in the beginning it only concerned public works, it marked an important stage, since no reference to the patented systems was made at all. All that was needed for the building was to be designed according to the law requirements, to be correctly carried out and well supported by a good reputation and experience of the company.

In spite of this new scenery, the use of patented systems still persisted in the professional practice. Well established and tested technologies were still preferred and considered more reliable. The case of the Viaduct of Bari is a good example of this tendency, since the Porcheddu Company managed it according to an experienced procedure.

In what the distinctive function of the patent consisted in this example we can only guess, since the official project was drafted according to the new prescriptions, definitely far-off from the «secret» method of calculation used for so many years by Hennebique.

Anyway, this circumstance well demonstrates the peculiar characterization of the reinforced concrete technology as an outbreaking invention, to such an extent that the forerunners and their inventions held for a long time a leading position.

On this subject, a curious remark can be done. By applying the celebrated method of the «half-and-half momentum», we can find that the amount of steel needed for the section is just the same that is foreseen by the modern method. Despite of the fine and accurate quality of the work, this technology is subject to the deteriorating action of time even more then masonry is. Moreover, the consciousness of the intrinsic defects brought up by aging is still scarce (together with the practice of techniques and methods of analysis and restoration). As a matter of fact, the problem of the restoration applied to concrete structures belongs to the contemporary age, with scientific and technical knowledge still being developed and experimented.

A question about the structural and functional rehabilitation of concrete works is now arising, and the discussion of the proposed case study opens quite a few interesting points of reflection and investigation.

There is first of all a generalized question about the interventions on a large scale in the existing fabric of the cities, the following re-qualification of the urban landscape and the management of the building heritage on the territory.

In Italy, both in the historical cores and in the outskirts, there is in fact a strong presence of r.c. buildings side by side with the traditional masonry constructions. The r.c. architecture ranges from the first realizations (at the beginning of nineteenth century) to the outbreak of the concrete technology and the related building trade in the 70’s. Not always it is characterized by a quality of architectural expression and construction as well. In many cases, the eventual perishability of this material (phenomenon still unknown and unexplored at that time) has now become evident and calls for urgent recovery.

Anyway, this minor but widespread building represents a relevant part of the residential housing in the Italian cities, for which structural safety and functional rehabilitation stand as primary question of scientific, social and territorial interest.

On the other hand, a lot of r.c. works belonging to the first decades of the twentieth century have become a landmark of historical and architectural significance and can be truly considered as monuments of the Modern. Despite of the many problems of durability and maintenance suffered by the material «concrete», these structures, born at the dawning of the new technology, still survive and have shown even better performances then many subsequent examples.

It is particularly important to study in detail the historical examples, and to recognize the characters
and the technical details of the solutions, if we wish to keep the trace of the history and preserve the evidence of the architecture and the structural science of the ‘900.

Reinforced concrete: open questions in the diagnostics, safety assessment and structural rehabilitation

For r.c. structures, it is worthwhile observing that only quite recently a knowledge of degradation and viscosity phenomena has been acquired, and the constructive detailing aimed at providing the quality of durability has been accordingly adopted.

Furthermore, it should be remembered that reinforced concrete works, from the origins (in the last decades of 1800) until the release of the first national technical laws (in Italy, the first one was released in 1907), were built by applying patented systems (i.e. the Monnier or the Hennebique system). These patented systems were often a result of individual intuitions more than a fruit of a coherent and established scientific and technical knowledge. This is one of the reasons why many of the structures built in those years, and still surviving, could not be considered reliable with regard to the static structural safety, as it is presently intended.

As a last element, but crucial all the same, we should point out that, in spite of the availability of advanced and reliable methods for the numerical and theoretical modeling of concrete, the safety assessment is characterized by a strong level of uncertainty, because of the poorness of the data that can be acquired about materials, building techniques, constructive details.

In the professional practice this aspect is often disregarded, since an unconditional confidence is usually devoted to modern materials and structural types, to which the designer is used.

But also in this case, the a-posteriori comprehension of an existing object is a complex process, inevitably incomplete and defective. The designer himself, even if he will probably be able to make a reasonable approximation, will never rule the structural response of his creation. In no way the application of scientifically based models in the design of a structure can assure the agreement between the foreseen behaviour and the actual one. In the practice, structures always show more or less relevant deviations from the prediction, and an undiscerning trust in the theoretical model is possibly dangerous more than deceiving.

The difficult task of the diagnostics is, then, to mark out the history of the building, reconstruct the geometrical, physical and mechanical features of the construction as they were designed and as they were actually realized (number and position of the reinforce bars, general arrangement of crucial nodes and sections, mechanical properties and technological characteristics of materials used).

For those buildings dated back to the period of the first experimenters and inventors of the reinforced concrete, the further problem of identifying the structural type of the examined case arise. In fact, the large diffusion of many different systems in the period between the end of 1880 and the beginning of 1900 makes it difficult for technicians to interpret the building technique used.

The rehabilitation procedure is always a complex process, relying on an integrated path of preliminary knowledge, analysis, decision-making and action (architectural interpretation, experimental investigation and testing, analytical modeling, choice of the intervention technique). For the reinforced concrete it becomes particularly tricky for different reasons.

First of all, unlike ancient constructions, a rooted tradition in restoration and repair is lacking in this field: since a few decades only interventions on concrete buildings have been faced, and this problem has been received in the academic and scientific circles.

Whereas the peculiar feature of masonry is the relative facility in being dismantled and reassembled, concrete is a monolithic material, and once a specific shape has been realized, it is a serious problem to vary it, or to intervene subsequently. Repair techniques must account for these difficulties, and innovative materials and techniques are being studied and experimented (concrete or metal jackets, fiber reinforced polymers, etc.).

The structural rehabilitation of the Viaduct in 1975

In 1975, repair and refurbishment of the structures of the Viaduct were needed in order to guarantee the
proper functioning of the railway (that is nowadays still in use).

Actually, the largest part of the interventions performed were not so severe, and concerned mostly the damage caused by water seeping, such as the crumbling of rebar cover and steel corrosion. Only foundations were affected by a more intensive care and suffered a real structural strengthening, with the construction of a new external concrete coating and the placement of additional reinforcement bars. Anyway, this rehabilitation case was in the forefront of restoration technology, at that time, with regard to the materials used. In fact, in order to avoid discontinuities between the existing structures and the new layers, tixotropic and epoxy mortars, having a controlled shrinkage, were used (fig. 7).

Foundations: the ground was excavated, in order to completely uncover the foundations; a concrete coating was realized that included part of the piers, and new steel reinforcement bars were placed under the ground level.

Elevation structures (main and secondary beams, piers, slabs, cantilever beams and balconies) all the damaged concrete covering (both the one already detached and that inadequately adherent) was eliminated by hydro-demolition (using smooth water jets). After uncovering the existing rebars, the rust was mechanically removed and, where required, brand new steel bars were placed to substitute the unrecoverable ones. Before reinstating the concrete covering, all reinforcements were treated with inhibitor of corrosion and passivating products. Afterwards, a high bond electrically welded wire netting was placed on the plank and the side beams. The concrete gaps were filled in with the tixotropic mortar. Finally, in order to guarantee serviceability conditions, the entire plank was made waterproof with a special mortar layer and pvc outlets were placed to divert meteoric water.

Dismissed Infrastructures: a Proposal for the Reuse

The Viaduct is located in a strategically central area of the city, but unfortunately its immediate surroundings suffer a condition of urban decay. The
image that the inhabitants of the area have is that of a place of ill fame and decline, spoiling the reputation of the neighborhoods.

In the last few years, a plan of general reorganization of the railway junction of the city has been conceived, that, when applied, will involve the abandoning of that rail branch. Once dismissed, the future existence of the Viaduct will be in jeopardy, considering also the negative image it has gained through the years, unless an alternative for its usage is not designed.

Indeed, the historical, scientific and cultural value of the concrete pieces of work of the early ’900 is widely recognized. It is beyond doubt that they are worth to be preserved as a landmark of the rising and development of a new technology that, from its origins on, has been welcomed as an outbursting innovation and since then has been associated, not always with impartiality, to the idea of Modern.

The case study of the Viaduct of Corso Italia in Bari is emblematic as regards to the exigency of retaining the cultural and historical evidence of an Age. The risk is to waste, under the pressing urge for a renovation and restoration of the City’s look, a precious but still unrecognized heritage—like it happened, for example, for many ancient buildings under the hunger for modernity and renewal characterizing the urban growth in the 60th.

These remarks should not be intended as an unconditioned and extremist praise of the conservatism in Architecture. On the contrary, it is opinion of the authors that the historical value of a building just consists in the richness of the historical subsidence. The monuments, as we see them today, are the result of long vicissitudes; alterations and rearrangements in order to be adapted to the different usage needs and tastes of the users. Indeed, the possibility of suiting changeable requirements often decides the same survival of the construction.

The problem is, eventually, to solve the question—both formal and static—of the relationship with the preexistence, trying to breed the raison d’être of the construction.

The arc-viaduct and the flyover: a scenery for the city of Bari

The first part of the line is an arc viaduct in traditional masonry work, and is located nearby the central railway station, in a lively, commercial area. The rest of the Viaduct, and in particular the one-kilometer long r.c. flyover, is instead more marginal, and despite its closeness to the centre, is plunged in a residential district, far from the shopping and walking routes, that are diverted towards more attractive roads.

In view of the plans of urban restoration that involve this construction, and as an alternative to a possible demolition, a rethinking of the functional use of the viaduct, no more touched by the running through of the trains, can be proposed. Not only this proposal is aimed at preserving a construction we consider of scientific and engineering interest, but indeed can offer a real chance of development to that part of the city and bring a new life, just taking advantage from the presence of that structure that is so hindered at the moment.

A green haven spanning the city traffic

The idea is inspired by a similar case: Le Viaduc des Artes, in the XII Arrondissement of Paris. Part of the

![Figure 8](Le Viaduc des Artes and the Promenade Plantée)
Vincenne railway and cast off in 1969, this viaduct was divested to the Municipality of Paris in 1986.

In four kilometres flying 9.18 meters high over the ground level, the local administration has created a pedestrian precinct spangled with a sequence of blooming roof gardens: the Promenade Plantée (fig. 8). Among bowers, fountains and benches, the promenade is an invitation to live the city under a different point of view, far from traffic jams and confusion. A thick green barrier gently protects the walkway, but nevertheless lets gleam through the life flowing far down. In fact, the project managed by the Municipality was not restricted to an operation of mere urban decoration, that could be easily doomed to fail, without having an actual spin-off for the district. Under the arches of the viaduct, 60 vaulted rooms house workshops and little handicrafts shops, in accordance with the craft vocation of the XII arrondissement (fig. 9–10). So, the Viaduct has become the showroom for jewel makers, sculptors, artists, embroiderers and lute-makers working in the calm of the ateliers made out of the restored bays of the bridge. And the impact on the quarter, before degraded and ill famed, has been very positive, even more than it was expected.

This is not an utopian, fantasy scenery. It’s an actual case of a clever and useful management of the resources of the city that, on the track of this short theoretical reflection, could be developed and successfully applied to the proposed case study.
REFERENCE LIST

8. La visione di una nuova architettura, Peter Collins; Casa Editrice il Saggiatore, Verona.