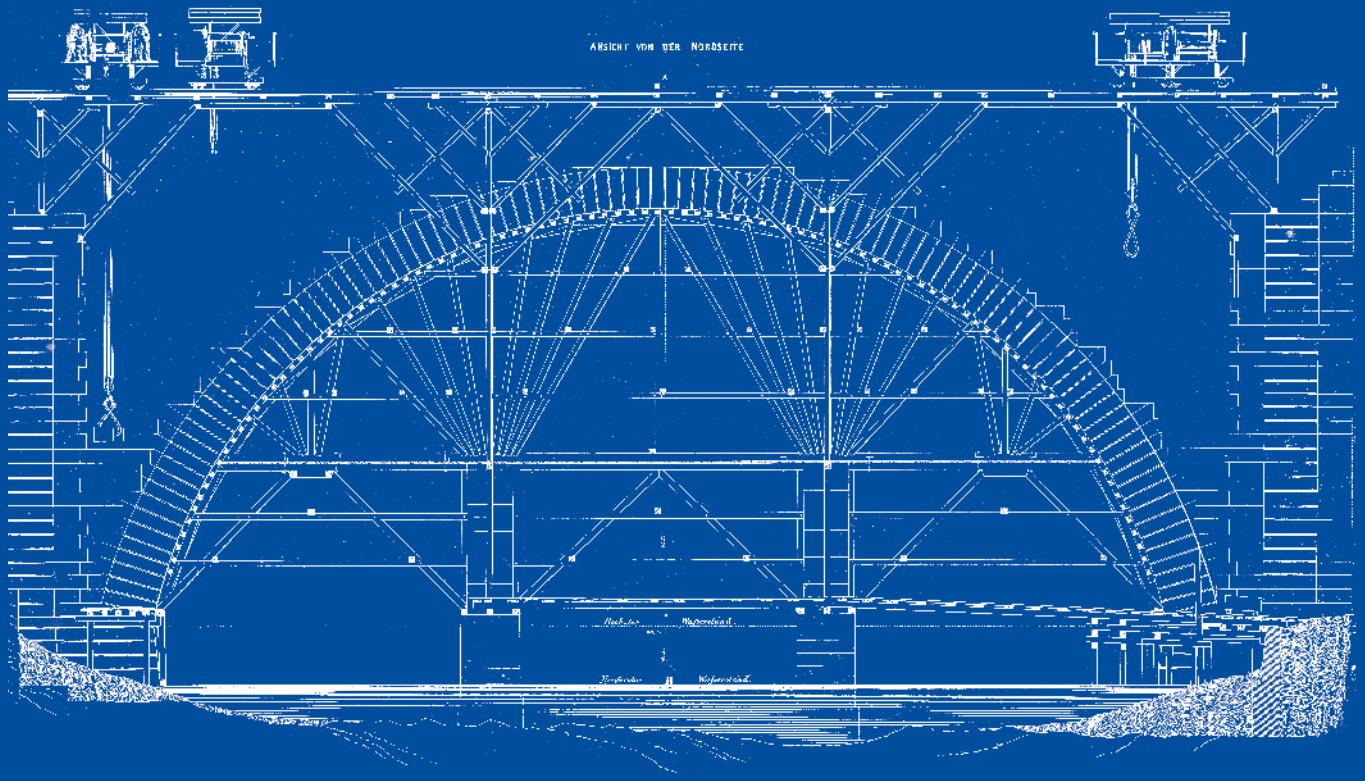
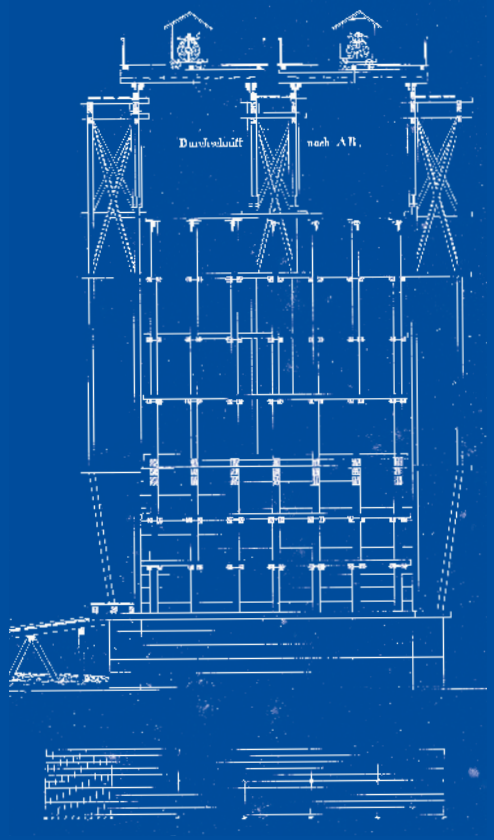
Proceedings of the 8th International Congress on Construction History
Stefan Holzer, Silke Langenberg, Clemens Knobling, Orkun Kasap (Eds.)




# Construction Matters



Stefan Holzer, Silke Langenberg,
Clemens Knobling, Orkun Kasap (Eds.)

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# Iron wires. The Seguin brothers and suspension bridges in the Grand Duchy of Tuscany and the Kingdom of Sardinia

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**Abstract:** The French scientific and production scenario played a "foreign enchantment" on the technicians and government staff of the Grand Duchy of Tuscany and the Kingdom of Sardinia, showing the evident influence of the *Grande Nation* on these countries. In the second half of 1820s these states pushed for the first time in Italy some significant experiments of an innovative type of bridge—the wire-cable suspension bridge—which had been introduced in France, just a few years before, by Marc Seguin. This was one of the prerequisites for the construction of two important bridges over the Arno which were designed and built by the Seguin's company: the San Leopoldo and San Ferdinando bridges. As for the Kingdom of Sardinia, the fascination for the technological progress beyond the Alps led to the network of relationships that the emerging Savoy entrepreneurship established with French and Swiss companies. This favored in Piedmont the design of first iron wire-cable suspension bridges by the Seguin brothers and the General Dufour. Piedmont's designs for suspension bridges never materialized, but the three most important bridges—La Caille, Casale, and Turin—were constructed just 15 years later, at the dawn of the 1940s. Through the research of archival sources, the paper aims to retrace the events that accompanied the construction of first wire-cable suspension bridges in Piedmont and Tuscany, to identify the features that characterized their diffusion in these countries and the role that Seguin brothers played both in terms of promotion of the construction typology and technological support.

## Introduction

Towards the end of the eighteenth century, ferrous alloy components were extensively used in the construction sector. In particular, some of the early research aimed at exploiting the mechanical properties of iron components focused on defining efficient technologies for bridge construction.

The so-called "traffic machines"—the iron bridges of the time (Parisi 2001, 331)—were an essential technical tool for implementing the trade policies of the most ambitious nations during that era. First studies initially based on the use of traditional building typologies or on the reinterpretation of "primitive structures" (Messina 1979, 242), later leading to processes of technological innovation and the definition of new building techniques and structural models.

In this scenario, research on the suspension bridges was a fertile field of experimentation. Its design was inspired by the structural types of rope bridges with liana or leather cables, which explorers had observed in China and some South American countries (Coltellini 1763, 120).

Due to their increasing availability in the market, iron alloy components gradually replaced materials used in traditional suspension bridges. Notably, the diverse range of ferrous products facilitated the emergence of two distinct technical and construction variants, which differed in component morphology and construction techniques: the chain bridge and the wire-cable suspension bridge.

In the first case, the suspension chains were configured with a catenary shape and consisted of either elongated rings or constrained bars. The wire-cable suspension bridge, on the other hand, required the use of different types of iron—pig and wrought iron—chosen on the basis of specific tensile tests. A technical problem linked to construction aspects of the second type consisted of the bending of wires at junctions, and its accurate solution was essential to produce long wires.

Chain bridges initially gained more popularity due to their immediate success in America, Great Britain, and later in Russia. In contrast, wire-cable suspension bridges spread slowly and were mainly used for the construction of narrow-span structures such as footbridges (Wiebeking 1834).

## 1. Marc Seguin and wire-cable suspension bridges

Marc Seguin was the grandson of the Montgolfier brothers. After studying in Paris, he returned in 1805 to his hometown of Annonay—a city in the Ardèche department, quite close to Lyon—where he began by enhancing the machinery of his family's business, and subsequently established numerous factories to produce felt.

Seguin's interest in promoting trade in his region through a modern and adequate infrastructure system, led him to study more efficient construction systems for river crossings. These systems needed to overcome the orographic obstacles that, at the time, limited the exchange of consumer goods. For the study of these construction systems, Seguin further implemented these studies after reading De Cheppe's article published in the *Gazette nationale or the Moniteur universel* (Seguin 1824, viij; De Cheppe 1821, 3–4). The article was a review of Joseph Cordier's book, *Historie de la Navigation Interieure*, and introduced Seguin to the suspension bridges

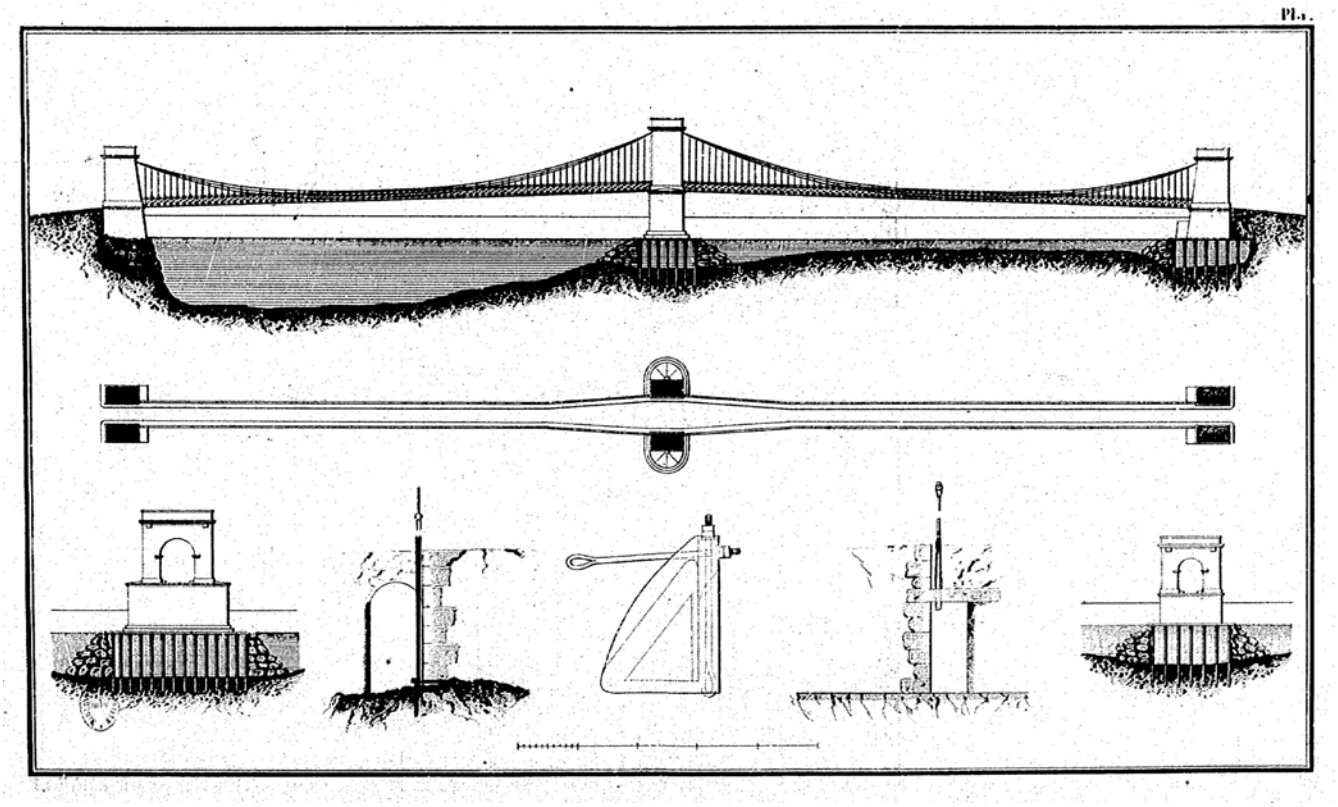


Figure 1. The bridge in Tournon: drawings (Seguin 1826, plate 1).

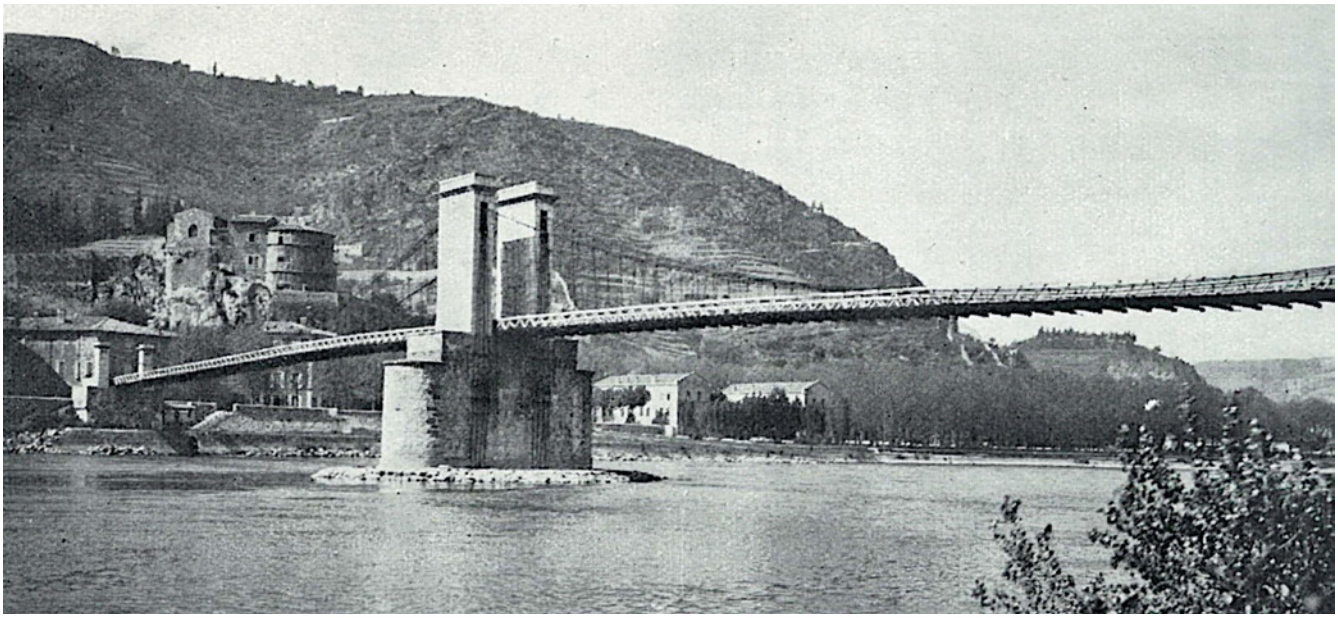


Figure 2. The bridge in Tournon by Marc Seguin, 1825: old postcard (Public Domain).

built in the United States of America (Cordier 1820, 172–185). This article and Thomas Pope's book on suspension bridges definitively convinced the Ardèche engineer to experiment with this typology (Pope 1811).

A first experimental test dated back to 1822, when he presented a proposal for a wire suspension footbridge of 18 m span on land he owned. During the same year, he was the author of a wire suspension bridge proposal with two 90-metre spans to link the towns of Tain and Tournon (Salençon 1987, 144). However, the General Council of Bridges and Roads in Paris, led by Claude-Louis Navier, rejected the project twice. Navier considered the calculations of the bridge's stability to be inadequate and imprecise. Furthermore, Navier made no secret of his personal predilection for the chain bridge type, to which he dedicated his treatise *Rapport a monsieur Becquey, conseiller d'état, directeur général des ponts et chaussées et des mines; et mémoire sur les ponts suspendus* (Navier 1823).

These early difficulties were then resolved by Seguin in the period 1824–1826, which represented a significant turning point. After continuous experiments and research, he succeeded in constructing two wire-cable suspension bridges and completed his first treatise, *Des ponts en fil de fer* (Seguin 1824). These efforts proved not to be in vain.

Indeed, the interest of a Commission of the Academy of Sciences granted Seguin the opportunity to resubmit the project for the Tournon Bridge to the General Council of

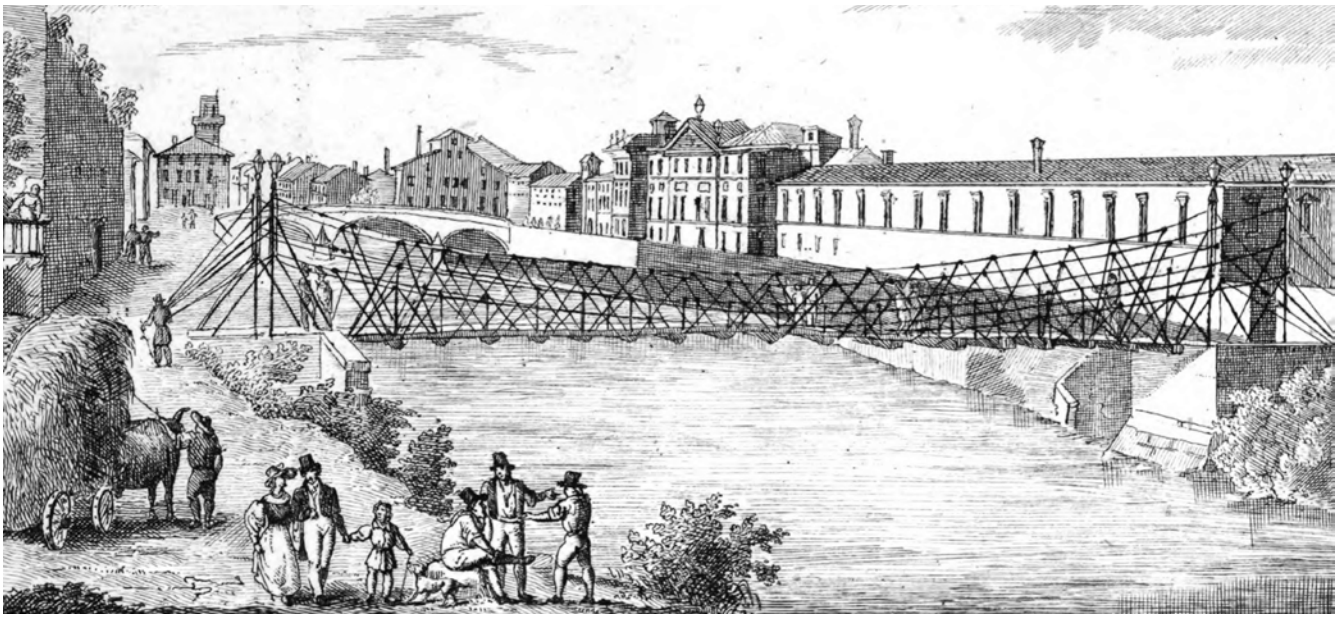


Figure 3. The bridge over the Bacchiglione River in Padua by Claudio Galateo ("Ponte di ferro a Padova", 1832, 471).



Figure 4. The bridge over the Caluso Canal at Aglié, by Ignazio Michela, 1830 (Archivio fotografico Città Metropolitana di Torino).

Bridges and Roads. The new proposal was considered "an excellent opportunity for experimentation" and, as a result, the construction was authorized. On August 25, 1825, the bridge was officially opened (Seguin 1826, 17). (Figures 1–2) As a result of this accomplishment, Marc Seguin became an internationally recognized designer. He also co-founded with his brothers a company that built in 25 years 186 bridges in France, Italy, and Spain (Dürrenmatt 1987, 115).

## 2. The scientific and technical scenario in Italy during Seguin's successful period

In Italian countries, technologies for iron bridge construction were imported mainly from France. Indeed, the *Grande Nation* played, in the peninsula, the role of complete dominance in the cultural, scientific, political, and economic fields. This French influence was increased by the significant delay of the Industrial Revolution in Italy. Jacobin ideals also inspired the renewal phase of the education system in the states of *Belpaese*: in the Napoleonic period, their forced political and administrative homogeneity led to the launching of a radical reform of cultural and scientific institutions; in particular, the model of the *Ecole Polytechnique* was the milestone for updating the education system for architects and engineers.

Between 1808 and 1814, the most significant opportunities "for French technical experts to export a policy of territorial transformation extensively experimented with in their homeland during the second half of the 18th century" (Parisi 2001, 335) were the projects for the bridge over the Po River in Turin and the one over the Garigliano River in Minturno.

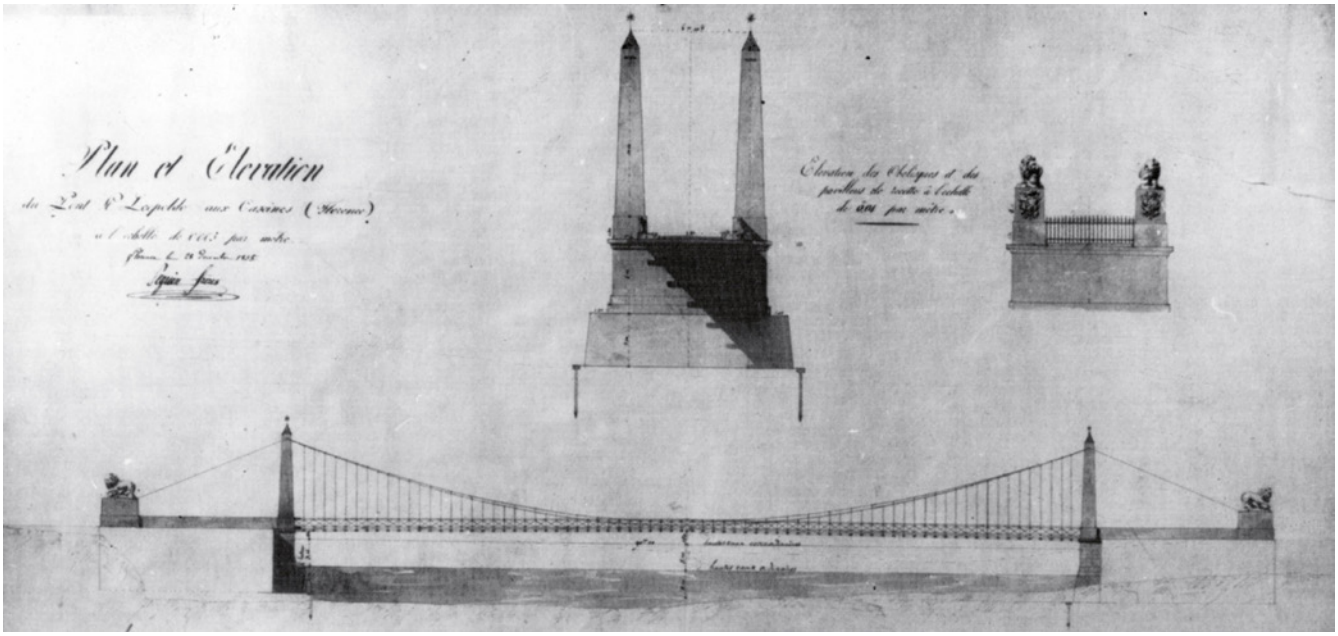



Figure 5. The San Leopoldo bridge: drawing (Segreteria di Finanze, Archivio di Stato di Firenze, by courtesy of Ministero della Cultura).

The first project led to the construction of an arch bridge, while the second proposed a suspension bridge that was never built.

The design by Luigi Giura for the first chain bridge in Italy dated back to 1828, a period during which experimentation of this type was also progressing significantly in other areas of the country.

The decisive condemnation of the Jacobin period in the years of the Restoration did not eradicate French technical mastership; its echo survived for a long time, just as the interest in transalpine projects remained alive and in those focused on improving infrastructure networks.

In this scenario, Marc Seguin played the role of the main character, emerging both as a designer and builder, due to the large number of bridges he constructed, and as a scientist for the widespread distribution of his treatise.

His magisterium mainly influenced two different areas, the Grand Duchy of Tuscany and the Kingdom of Sardinia; as a consequence, these countries became the most important locations in Italy for the experimentation of wire-cable suspension bridges.

Not only in these areas but also in a few others, such as Veneto, the building of long-span bridges was preceded by a considerable number of footbridge projects with small spans that tested the concept of suspension bridges. One of the first was an eight-meter-long wire-cable suspension bridge in Sesto Fiorentino, designed by engineer Antonio Carcopino in 1825. Local iron was used in its construction. In 1828, Anton Claudio Galateo was the author of the bridge over the Bacchiglione River in Padua (Chevalier 1828). (Fig. 3)

Subsequently, in the Kingdom of Sardinia, King Carlo Alberto promoted the building of footbridges in the Royal Park of Racconigi.

These were succeeded by the removable crossing over the Caluso Canal at Aglié, designed in 1830 by the engineer Ignazio Michela for the notary Vitale Prié. (Fig. 4)

The Ombrone Bridge was built in 1833. Its designer, the engineer Alessandro Manetti, chose the iron wire-cable suspension bridge for its technical advantages and the savings in construction time and cost (Lensi and Orlandi 1987, 44). Later, Manetti himself, at his highest position within the Tuscany Engineers' Corps, took part as a consultant in the building of the Tuscan bridges by Marc and Jules Seguin's company.

## 3. New experimental territories: Tuscany and the construction of bridges over the Arno

When Leopold II became Grand Duke of Tuscany in 1824, he launched a series of reforms of the public administration that did not hesitate to recover the best initiatives introduced under Napoleonic rule. It is no coincidence that the institution of the "Corps of Engineers" seemed to be in continuity with what the French government had itself created in Florence, the "Imperial Service of Bridges and Roads", a direct emanation of the *Service Impérial des Ponts et Chaussées*. Consequently, when the need arose to build two large bridges over the Arno near Florence, the Grand Duchy's leadership turned to the technological innovations proposed by the French manufacturing scenario of those years, in which the company founded by the Seguin brothers (Seguin 1835) played a leading role. These were the conditions that led to the French company being awarded the contract. The firm began the project by establishing a joint-stock company to build the bridge and collect tolls for at least a century, following a practice that was likely already in use. The two bridges cost 595,238 Tuscan lire.

Seguin's project was widely criticized for being inadequate given the hydrographic features of the Arno. The French engineers proposed a 90-meter-spanning suspension bridge with abutments inside the riverbed that could be accessed from the banks via embankments, despite the riverbed's broad range of 144 to 157 meters. (Fig. 5) Pasquale Poccianti also objected to this arrangement, pointing out the risk of regions of sediment deposition forming close to the historic center (Venturi 1870).

In January 1836, Leopoldo II gave his approval to the project on the only condition that the bridge be tested once

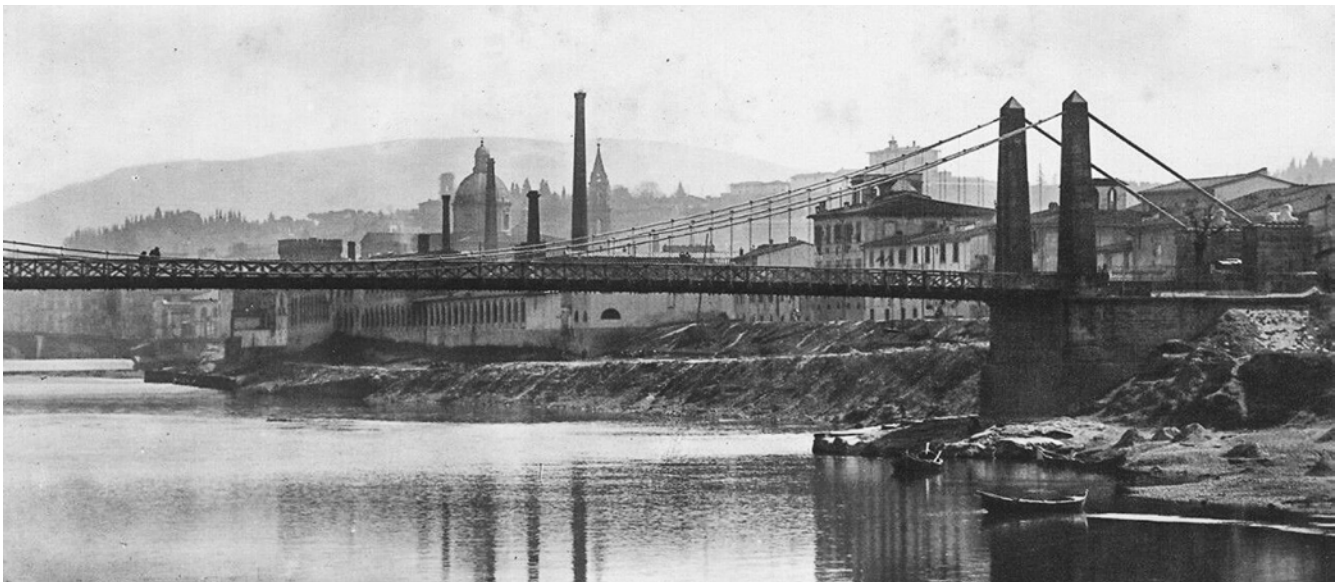


Figure 6. The San Leopoldo Bridge in Florence: old postcard (Public Domain).

Manetti's technical requirement was verified. The Seguins integrated the project with drawings they had already developed for the bridge at Bry-sur-Marne. Not long later, the French company also presented the Grand Duke with a proposal for a second bridge near Porta San Niccolò that would bear San Ferdinando's name. It was entirely similar to the previous one.

The construction of the two bridges began in the spring of 1836. Pairs of columns spaced 5 meters apart, resembling Egyptian obelisks in shape, served as supports for the suspension cables. They were made of stone and perforated just below the pyramid-shaped tops, to hold square cast iron plates measuring 1.10 m on each side.

The cables consisted of 4 pairs of bundles, each containing 320 iron wires with a diameter of 3.42 mm. The cables bent at the cast iron plates placed inside the masonry blocks positioned on the abutments and were tensioned at the ends by counterweights.

Cast iron devices alternately connected pairs of beams with tie rods, consisting of cables with a circumference of 23 mm and composed of 50 iron wires with a diameter of 2.7 mm. Each tie-rod supported the end of one of the 74 beams of the deck, composed of a pair of 16-cm-high I-shaped iron profiles with a square-section oak crossbeam in between, connected by bolts (Tognetti 1910).

The bridge deck measured 90 meters long and 5.75 meters wide. On the underside of the deck pairs of girders, also configured as I-shaped profiles, served to maintain a constant distance between the cross girders and reduce sway. On the upper side, an iron beam separated the floor, which consisted of a double layer of oak and pine boards, from the raised floor of the wooden sidewalk, which supported the side parapet.

The bridges were officially inaugurated at the end of 1837, but only six years later an exceptional flood revealed the validity of the criticisms that had emerged during the project phase. (Figures 6–7)

In November 1844, the Arno River overflowed, causing the collapse of the San Ferdinando Bridge and damaging the historic *Ponte delle Grazie* located downstream. The bridge was reconstructed at the expense of the shareholders of the Joint-Stock Company in the early 1850s, and the work was entrusted to Felice Francolini, an engineer-architect of the General Directorate for Water and Road Works and Civil Buildings of the State. Despite the evident inadequacy of the original bridge, he did not make any modifications to Seguin's design.

In 1890, the San Ferdinando Bridge was replaced with a steel structure by the Impresa Italiana Industriale di Costruzioni Metalliche, directed by Alfredo Cottrau. In contrast, the Cascine Bridge was undamaged by the 1844 flood, likely due to its different location. However, it immediately showed problems with wear and tear of the deck, resulting from excessive oscillations caused by the passage of vehicles and pedestrians.

For this reason, in July 1851, regulations were issued to control the traffic, which was still discouraged for military troops (Ponti sospesi sull'Arno 1881). Falling into disuse, the bridge was eventually replaced in the 1930s by the Ponte alla Vittoria, constructed with a reinforced concrete structure.

## 4. A missed opportunity: Piedmont and the Casale Monferrato bridge project

The French scientific and production context also exerted a "foreign enchantment" (Re 2020) on the technicians and government staff of the Kingdom of Sardinia, confirming the undeniable influence of the *Grande Nation* on the countries closest to it. It is no coincidence that Piedmont and Liguria were not included in the new borders of the Kingdom of Italy established in 1805 but were annexed directly to the Napoleonic Empire. Even the voices raised in Turin against the Jacobin heritage after the Congress of Vienna did not seem to diminish the interest and admiration for the French scientific and technological progress, appreciated even by most of the Piedmontese government institutions. This interest led to experimentation with iron wire-cable suspension bridges in the Kingdom of Sardinia, where design opportunities arose just a few years after the initial experiences conducted by the Seguin brothers and General Dufour in France and Switzerland.

However, these proposals were unbuilt; instead, the three most important projects—the La Caille, Casale, and Turin bridges—were built only fifteen years later, at the dawn of the



Figure 7. The San Ferdinando Bridge in Florence (Archivio Alinari, Firenze).

early 1840s. These bridges stood out in the Italian engineering panorama of the time for their structural records in terms of span width. The failure to implement the proposals of the second half of the 1820s and early 1830s cannot diminish the role played by Dufour and Seguin in these events and the undeniable and precious technical-scientific contributions they provided to the Piedmontese professional community. While the Swiss general proposed the design for the La Caille and Valentino bridges in the center of Turin (Peters 1987, 57), the French technician was the author of the project for the bridge over the Po River at Casale Monferrato.

To replace the floating bridge that was built in the 15th century and ensured the road connection between Alessandria and Vercelli, Seguin proposed in 1830 a project for a bridge in Casale similar to the one built in Tournon in 1828. Carlo Bernardo Mosca, secretary of the Superior Council of Bridges and Roads, sought and authorized the project (Comoli, Guardamagna, and Viglino 1997, 116).

Seguin designed a two-span bridge with a suspension system supported by three pairs of pillars and four sets of wire cables. One of the piers sustaining each couple of pillars was placed in the center of the riverbed and resembled majestic arches. The technical details of the tie rods and the hardwood deck were similar to those designed by the French engineer in other contemporary works. (Fig. 8) Local interests opposed its construction preferring the preservation of the floating bridge to collect tolls on it.

The project was abandoned but not forgotten, as evidenced by its rediscovery less than two decades later when the conditions for the construction of the bridge finally matured.

In July 1838, a contract was signed for the construction of the bridge. The work was entrusted to the Lyon-based company of Louis Bonnardet, who was also responsible for the construction of a previous bridge at La Caille in Savoy and the subsequent one at Valentino. The project's financing was provided by Bonnardet's partner, Antoine Blanc, who held the toll concessions for a period of 29 years and 10 months. The project designer and the director of works, Émile Belin and Paul Léon Le Haître, respectively, were the same engineers appointed for the project in Savoy.

The echo of Seguin's proposal did not go unheard; in fact, Belin adopted the two-span scheme with a central couple of pillars in the riverbed, even though Bonnardet's company had mainly constructed single-span bridges up to that time (Ponte sospeso 1840).

Belin reinterpreted the project of his illustrious predecessor, adapting it to the dimensions and site conditions: the spans were extended to 95 m in length, which was 5 m more than the bridge in Tournon; the central pier in the riverbed was shifted towards the left bank of the Po. This configuration altered the bridge's symmetry with respect to the riverbed in order to use an ancient "prismata"—a stone structure for the protection of riverbanks against erosion—to limit foundation works for the abutment near the city center (Tessiore 1869, 11). The central pier in the riverbed and the overlapping pair of pillars were configured as a neoclassical monumental arch. Pillars supported the suspension cables but were also designed for their anchoring, with the iron cables housed in "specially created grooves" between the masonry and the stone clad. Each of the suspension cables, 4 on each side, had a section of approximately 6 cm in diameter; the central pier also provided support for the ends of the deck, which was located 10 m above the low-water level of the river, with the expectation that this height could be maintained at least 5.5 m above the water's surface during peak floods.

In March 1839, construction began, but in October of the same year, the project faced a crisis due to an exceptional event: a sudden flood of the Po River, which resulted in the collapse of the left abutment, and damage to the central pier, and to the "prismata" on the opposite bank. Additionally, the cables fell into the water. This led to a dispute between the General Intendency of the Kingdom and Bonnardet's company, primarily focusing on the proper execution of foundation work. The final agreement they signed foresaw the improvement of the stability of the foundation systems with the insertion of "robust iron bolts". Subsequently, construction work resumed in January 1840 and was completed in August of the same year (Nota 1839, 11).

Despite the problems that emerged during the construction process, the two-span layout and the technical and construction solutions used in this bridge were widely



Figure 8. Project of the suspension bridge in Casale Monferrato by Marc Seguin, 1830 (coll. Dis. Figura 5. vari I.127, già O.VII.106, Musei Reali, Biblioteca Reale di Torino).

appreciated. For instance, Morandière included this bridge in his Treatise as the only example of a suspension bridge built in Italy—La Caille was listed among the French examples—(Morandiere 1888, 1491). (Fig. 9)

Furthermore, the bridge was a reference model for the project and construction of the bridge over the Tanaro River in Asti, designed by engineers of the Kingdom of Sardinia, led by Pietro Bosso.

## Conclusion

In the historical and cultural context of pre-unification Italy, the figure of Marc Seguin stands as a vivid demonstration of two significant aspects of the scientific and technical evolution linked to the "Iron Revolution" (Sutherland 1977, xiii): the revolution allowed the mass production of iron materials; it also marked the beginning of experimentation in a privileged field, such as civil engineering works.

The French entrepreneur was the emblem of the transalpine scientific and cultural *koinè* started under Napoleonic occupation and continued during the Restoration years, which was exercised directly through the importation of his wire suspension bridge model.

At the same time, he represents a different and demiurgic pontifex figure who not only "capitalizes on what is new in the practical translation of scientific thought" (Dassori 2020, 12) but also assumes a new status "less and less an artist in the service of a prince" and more and more "responsible for a more collective form of progress" (Picon 2006, 9) by promoting, at a supranational level, the exchange and experimentation of acquired knowledge and establishing new relations with the world of industry, land ownership and finance.

Despite the problems that emerged during the construction process, the two-span layout and the technical and construction solutions used in this bridge were widely appreciated. For instance, Morandière included this bridge in his Treatise as the only example of a suspension bridge built in Italy—La Caille was listed among the French examples. Furthermore, the bridge was a reference model for the project and construction of the bridge over the Tanaro River in Asti, designed by engineers of the Kingdom of Sardinia, led by Pietro Bosso.


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Figure 9. Carlo Alberto Bridge in Casale Monferrato: general view (Fotografia 11B23, Fondo Fotografico Francesco Negri, Biblioteca Civica Giovanni Canna di Casale Monferrato).


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Construction History is still a fairly new and small but quickly evolving field. The current trends in Construction History are well reflected in the papers of the present conference. Construction History has strong roots in the historiography of the 19th century and the evolution of industrialization, but the focus of our research field has meanwhile shifted notably to include more recent and also more distant histories as well. This is reflected in these conference proceedings, where 65 out of 148 contributed papers deal with the built heritage or building actors of the 20th or 21st century. The conference also mirrors the wide spectrum of documentary and analytical approaches comprised within the discipline of Construction History. Papers dealing with the technical and functional analysis of specific buildings or building types are complemented by other studies focusing on the lives and formation of building actors, from laborers to architects and engineers, from economical aspects to social and political implications, on legal aspects and the strong ties between the history of construction and the history of engineering sciences.

The conference integrates perfectly into the daily work at the Institute for Preservation and Construction History at ETH Zurich. Its two chairs – the Chair for Building Archaeology and Construction History and the Chair for Construction Heritage and Preservation – endeavor to cover the entire field and to bridge the gaps between the different approaches, methodologies and disciplines, between various centuries as well as technologies – learning together and from each other. The proceedings of 8ICCH give a representative picture of the state of the art in the field, and will serve as a reference point for future studies.

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