HISTORY OF CONSTRUCTION CULTURES

VOLUME 2

edited by
João Mascarenhas-Mateus
and **Ana Paula Pires**

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History of Construction Cultures

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Introduction: *History of Construction Cultures*

We are what we build and how we build; thus, the study of Construction History is now more than ever at the centre of current debates as to the shape of a sustainable future for humankind. Embracing that statement, the present work takes the title *History of Construction Cultures* and aims to celebrate and expand our understanding of the ways in which everyday building activities have been perceived and experienced in different cultures, times and places.

This two-volume publication brings together the communications that were presented at the 7ICCH – Seventh International Congress on Construction History, broadcast live from Lisbon, Portugal on 12–16 July 2021. The 7ICCH was organized by the Sociedade Portuguesa de Estudos de História da Construção (Portuguese Society for Construction History Studies – SPEHC); the Lisbon School of Architecture, University of Lisbon; its Research Centre (CIAUD); and the College of Social and Human Sciences of the NOVA University of Lisbon (NOVA FCSH).

This is the first time the International Congresses on Construction History (ICCH) Proceedings will be available in open access format in addition to the traditional printed and digital formats, embracing open science principles and increasing the societal impact of research. The work embodies and reflects the research done in different contexts worldwide in the sphere of Construction History with a view to advancing on the path opened by earlier International ICCH editions. The first edition of ICCH took place in Madrid in 2003. Since then, it has been a regular event organized at three-year intervals: Cambridge (2006), Cottbus (2009), Paris (2012), Chicago (2015) and Brussels (2018).

7ICCH focused on the many problems involved in the millennia-old human activity of building practiced in the most diverse cultures of the world, stimulating the cross-over with other disciplines. The response to this broad invitation materialized in 357 paper proposals. A thorough evaluation and selection process involving the International Scientific Committee resulted in the 206 papers of this work, authored by researchers from 37 countries: Australia, Austria, Belgium, Brazil, Bulgaria, Canada, China, Dominican Republic, Ecuador, Egypt, Estonia, France, Germany, India, Iran, Ireland, Italy, Japan, Mexico, Netherlands, New Zealand, Norway, Peru, Poland, Portugal, Puerto Rico, Russia, Serbia, Spain, South Africa, Sweden, Switzerland, Thailand, United Arab Emirates, United Kingdom, United States of America, and Venezuela.

The study of construction cultures entails the analysis of the transformation of a community's knowledge capital expressed in the activity of construction. As such, Construction History is a broad field of knowledge that encompasses all of the actors involved in that activity, whether collective (contractors, materials producers and suppliers, schools, associations, and institutions) or individual (engineers, architects, entrepreneurs, craftsmen). In each given location and historical period, these actors have engaged in building using particular technologies, tools, machines and materials. They have followed specific rules and laws, and transferred knowledge on construction in specific ways. Their activity has had an economic value and belonged to a particular political context, and it has been organized following a set of social and cultural models.

This broad range of issues was debated during the Congress in general open sessions, as well as in special thematic sessions. Open sessions covered a wide variety of aspects related to Construction History. Thematic sessions were selected by the Scientific Committee after a call for proposals: they highlight themes of recent debate, approaches and directions, fostering transnational and interdisciplinary collaboration on promising and propitious subjects. The open sessions topics were:

– Cultural translation of construction cultures: Colonial building processes and autochthonous cultures; hybridization of construction cultures, local interpretation of imported cultures of building; adaptation of building processes to different material conditions;
– The discipline of Construction History: Epistemological issues, methodology; teaching; historiography; sources on Construction History;
– Building actors: Contractors, architects, engineers; master builders, craftspeople, trade unions and guilds; institutions and organizations;
– Building materials: Their history, extraction, transformation and manipulation (timber; earth, brick and tiles; iron and steel; binders; concrete and reinforced concrete; plaster and mortar; glass and glazing; composite materials);

– Building machines, tools and equipment: Simple machines, steam operated-machines, hand tools, pneumatic tools, scaffolding;
– Construction processes: Design, execution and protective operations related to durability and maintenance; organization of the construction site; prefabrication and industrialization; craftsmanship and workshops; foundations, superstructures, roofs, coatings, paint;
– Building services and techniques: Lighting; heating; ventilation; health and comfort;
– Structural theory and analysis: Stereotomy; modelling and simulation; structural theory and structural forms; applied sciences; relation between theory and practice;
– Political, social and economic aspects: Economics of construction; law and juridical aspects; politics and policies; hierarchy of actors; public works and territory management, marketing and propaganda;
– Knowledge transfer: Technical literature, rules and standards; building regulations; training and education; drawings; patents; scientific dissemination, innovations, experiments and events.

The thematic sessions selected were:

– Form with no formwork (vault construction with reduced formwork);
– Understanding the culture of building expertise in situations of uncertainty (Middle Ages-Modern times);
– Historical timber constructions between regional tradition and supra-regional influences;
– Historicizing material properties: Between technological and cultural history;
– South-South cooperation and non-alignment in the construction world 1950s–1980s;
– Construction cultures of the recent past: Building materials and building techniques 1950–2000;
– Hypar concrete shells: A structural, geometric and constructive revolution in the mid-20th century;
– Can engineering culture be improved by construction history?

Volume 1 begins with the open session "Cultural translation of construction cultures" and continues with all of the thematic sessions, each one preceded by an introductory text by the session chairs. The volume ends with the first part of the papers presented at the open sessions, organized chronologically. Volume 2 is dedicated to the remaining topics within the general themes, also in chronological order.

Four keynote speakers were chosen to present their most recent research results on different historical periods: Marco Fabbri on "Building in Ancient Rome: The fortifications of Pompeii"; Stefan Holzer "The role of temporary works on the medieval and early modern construction site"; Vitale Zanchettin "Raphael's architecture: Buildings and materials" and Beatriz Mugayar Kühl "Railways in São Paulo (Brazil): Impacts on the construction culture and on the transformation of the territory".

The editors and the organizers wish to express their immense gratitude to all members of the International Scientific Committee, who, despite the difficult context of the pandemic, worked intensively every time they were called on to give their rigorous evaluation of the different papers.

The 7ICCH was the first congress convened under the aegis of the International Federation of Construction History, founded in July 2018 in Brussels. Therefore, we are also very grateful to all the members of the Federation, composed of the presidents of the British, Spanish, Francophone, German, U.S. and Portuguese Societies and its Belgian co-opted member. A special thanks is due for all the expertise and experience that was passed on by our colleagues who have been organizing this unique and world significant event since 2003, and in particular to our predecessors from all the Belgian universities who organized 6ICCH.

The editors wish to extend their sincerest thanks to authors and co-authors for their support, patience, and efforts. This two-volume work would not exist but for the time, knowledge, and generosity they invested in the initiative.

Our sincere thanks also go out to Kate Major Patience, Terry Lee Little, Kevin Rose and Anne Samson for proofreading every paper included here, and to the team at Taylor & Francis (Netherlands), in particular Germaine Seijger and Leon Bijnsdorp.

Finally, we are grateful to all members of the Local Committee and to the institutions that have supported both the 7ICCH event and the publication of these proceedings.

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Open session: Political, social and economic aspects

History of Construction Cultures – Mascarenhas-Mateus & Paula Pires (eds)

Swing bridges in the 19th century Italian dockyards

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ABSTRACT: Italian Unification in 1861 fostered a reorganization of national infrastructures in order to adapt them to the status of other European countries. The strategic Navy sector was implemented with a new equipment supply system in order to achieve functional and autonomous weaponry production and to develop a network of shipbuilding and defensive structures. This infrastructural system pushed a multi-year plan of refurbishment and newly founded Italian dockyards, which included experimentation with the swing bridge built in iron and steel structures. This bridge design was already known on the peninsula with models in a wooden construction tradition. This produced an original variation in the second half of the 19th century due to the influence of French and British models. Its construction combined multiple specializations of Italian engineering, involving national iron and steel construction, eager to obtain its technical and economic affirmation.

1 ORIGINS OF SWING BRIDGES IN ITALY

The swing bridge, which took origin from the drawbridge used in defensive structures such as fortresses and castles, was used to cross navigable canals and guaranteed both the passage of boats and the connection between the banks for the transit of people, livestock and goods. Its short span, the light loads and the structural typology, made possible a rigid rotation around a single pin placed on a bank or sunk into the riverbed, leading to the choice of wood for its construction, incorporating also iron components and ropes for the completion of the structure. For small spans of 6–8 meters, structural layouts would have resembled traditional wooden roofs while more complex solutions were conceived for greater spans, such as the original proposals of Leonardo Da Vinci (Bernardoni 2020). In Italy, several swing bridges were used over narrow rivers and they were characterized by warped deck and wooden frames: paradigmatic cases include the bridges that from the 17th century defined several connections along the Canal Navile in Bologna (Matulli & Salomoni 1984).

The use of wood continued until the early decades of the 19th century, when cast iron and iron construction pieces gradually became common. This transition is well represented by the swing bridge of Senigallia harbour built in 1827 (Mancini 1834).

From the mid-19th century, cast iron and iron began to be applied to the whole bridge structure, with the exception of the deck and secondary frame parts, introducing new technical and figurative potential. Meaningful cases of this conception were: the bridge over the Grand Canal of Trieste built in 1857 (Vio 1887) and the three bridges built over the River Brenta near Venice (Figures 1, 2).

Advancements in this construction typology could later be found in the several swing bridges that the Royal Italian Navy had constructed within the scope of the refurbishment and expansion of dockyards and their infrastructures. This process was characterized by the importation of foreign models with two pins and turning spans, especially used in France, that became the national construction practice reference.

2 THE ROYAL NAVY AND ITS INFRASTRUCTURAL DEVELOPMENT

After the declaration of the Kingdom of Italy, the Royal Navy immediately attained an important position in a country that was "mainly maritime" (Ferrante 2018). The debate on the development of the fleet and weaponry production grew strongly and decisively following the disastrous defeat of Lissa in 1866. This ruinous battle revealed the Italian shortcomings both in terms of military strategies and the navy's equipment.

Ministers Riboty and Saint-Bon started a renewal plan that involved several aspects: the manufacture of efficient warships, the replacement of obsolete vessels, the completion and construction of dockyards and military ports, with the consequent plan for the coordination of the respective fleets. Between 1867 and 1882, the Royal Navy inaugurated three new dockyards (La Spezia, Messina and Taranto) and provided for the refurbishment of the dockyards in Livorno and Venice (Gabriele & Friz 1982).

A leading figure in the modernization program was General Benedetto Brin, initially Director and then Minister of the Navy's Ministry. Brin was the main supporter of the construction of large warships and also promoted the development of heavy industry, primarily the steel industry, to support the production and the equipping of warships. The increasing tonnage of battleships required the construction of increasingly wider canals, docks and dry-docks in the harbours; as

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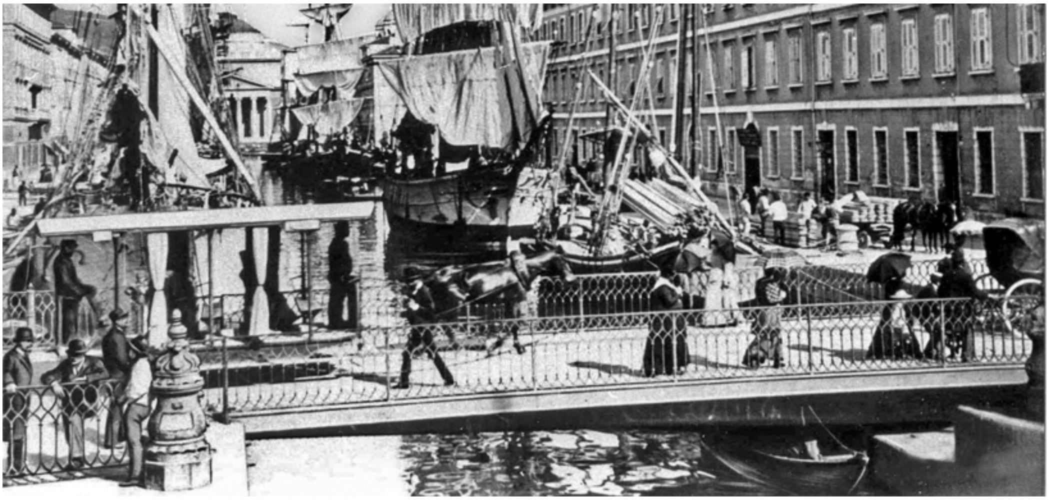


Figure 1. Swing bridge over the Grand Canal of Trieste built in 1857 (Vio 1887).

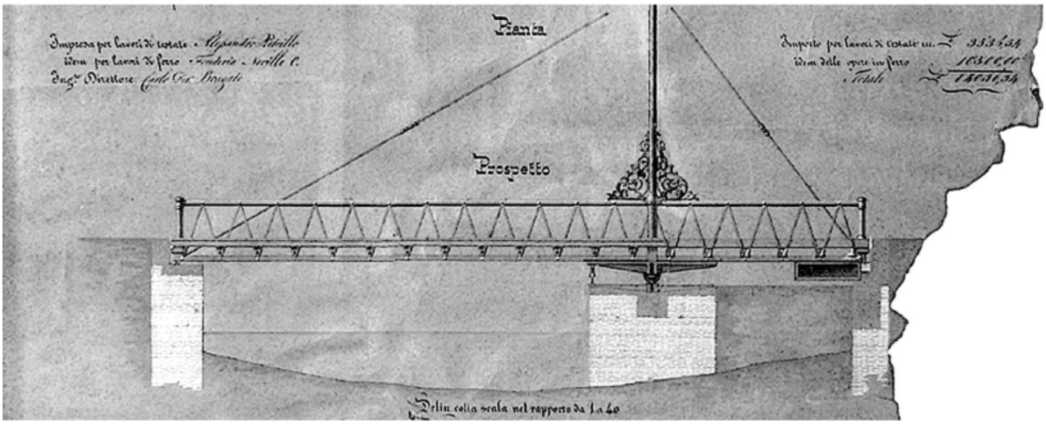


Figure 2. One of the three swing bridges built over the River Brenta near the Venice Lagoon (Comune di Mira 2008).

a consequence, bridges were built in order to ensure connections between the different banks and also to control maritime access.

Large span swing bridges were introduced in Italian military ports; their design concept mainly focused on two construction models: a one or two rotation pin bridge inspired by case studies drawn from countries that already possessed consolidated military forces and port infrastructures suitable for the movement of large warships. In particular, the British and French models represented an important cultural reference for the Italian engineers who were charged with this bridge typology. In particular Italian designers preferred the model with two pins and turning spans as used in the dockyards of Livorno, La Spezia and Taranto.

A common aspect of these experiences emerges in the building company, the Anglo-Neapolitan Guppy & C which was commissioned to build the swing bridges in Livorno and La Spezia. In the case of Taranto, their proposal was rejected and awarded to the IICM (Industria Italiana di Costruzioni Metalliche – Italian Industry of Iron Construction) company directed by the Neapolitan engineer Alfredo Cottrau. Guppy & C boasted a long-lasting relationship with military institutions that started out during the reign of the Two Sicilies and continued after the Unification of Italy. The founder Thomas Guppy had collaborated in the UK with one of the great icons of British engineering, Isambard Kingdom Brunel (Angus Buchanan 2001). After Guppy's arrival in Italy, he founded the Neapolitan company with his partner John Pattinson, which also contributed to the construction of several iron bridges (Doe & Green 2017).

2.1 *The Livorno dockyard swing bridge*

The new programs of the Kingdom of Italy involved deep change for the commercial role of Livorno. The status of free port was removed and the government aimed at transforming the city into a construction

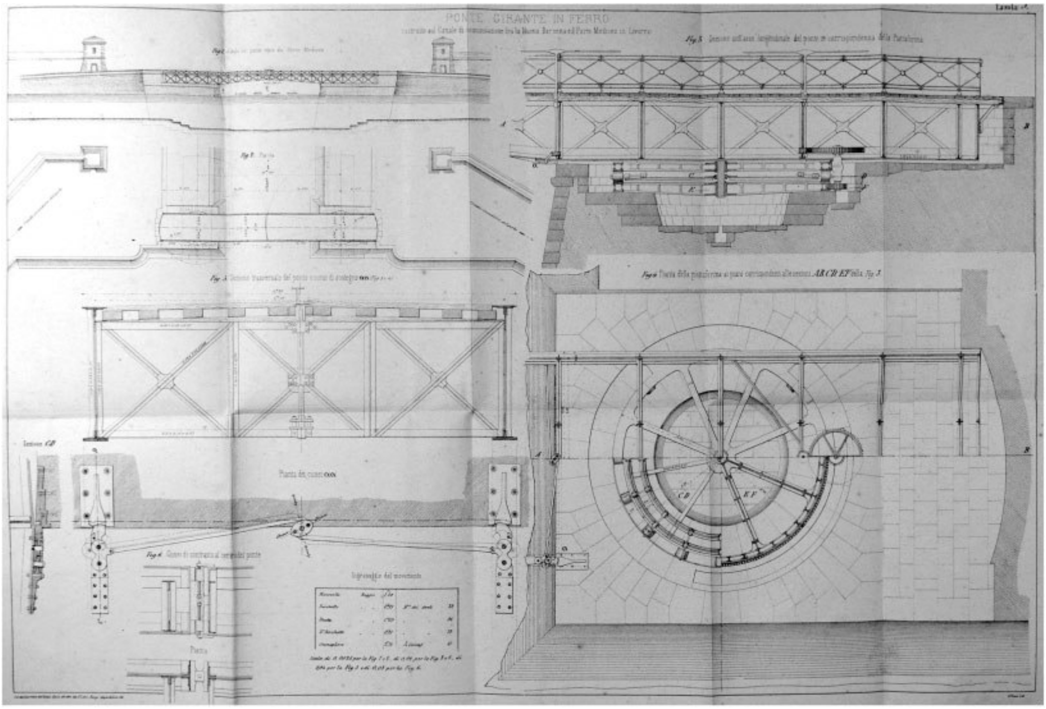


Figure 3. Construction details of the swing bridge built in the new dockyards of Livorno and inaugurated in 1868 (Mati 1869).

centre of large passenger and naval ships (Montgomery Stuart 1876). Therefore, the harbour needed improving and continuing the extension works, already launched in the final years of the Grand Duchy of Tuscany according to the project by the French engineer Victor Poirel.

With the law of July 1861, the Kingdom of Italy accepted the proposal of the colonel and naval engineer Vladimiro Chiavacci, who sought to carry out the works at his own expense in exchange for certain concessions. Observations by the technicians charged by the Ministry of Public Works and Maritime Affairs extended the Chiavacci plan to include the addition of a new dockyard and the construction of two bridges: the first one unmovable for connecting with the city and a mobile second bridge at the port entrance (Marzucchi 1861).

The construction of the new sections of the harbour was managed from 1864 to 1867 by the Fortini, Rinaldi and Comp., which completed the masonry supports of the mobile bridge in eight months. The foundations were sunk to 8 meters below ground level while the abutments rose to 2.5 meters above sea level (Figure 3).

In February 1867, the design for this two pin iron swing bridge, supervised by the engineer Tommaso Mati, was proposed to the Maritime Affairs management and the bridge building contract awarded to the Guppy & C company based in Naples. Each turning span of the bridge was 21 meters long and divided into three parts: the base was 7 meters long, the pin section was 4 meters long with the cantilevered section 10 meters long and forming a low half arch. The bridge deck was 5 meters wide and allowed the passage of people and vehicles when closed and the exit of ships built in Livorno when open.

Work began in October of the same year with the assembly of the pins on the masonry supports, which were shaped with a cylindrical introflexed compartment. The pins were composed of two iron cogged wheels – with a diameter of 5.40 meters, a stiffened rectangular section and eight spokes – connected to two other concentric wheels without spokes. The lower wheel was fixed in the masonry through "screw pivots and a concrete cast"; the collaboration with the upper wheel was guaranteed by 48 iron bearings of different sizes and a mechanism equipped with cogged wheels. The next phases concerned the assembly on the rotation pins of the turning span parts that included the counterweight far ends (Mati 1869).

The iron structure of each turning span consisted of two iron girders, joined by eleven horizontal members. The I shaped section of upper and lower members was composed by different profiles, stiffened according to the influence of the load. The vertical and diagonal members were built of L shaped profiles. Riveted joints were concealed along the truss ladders by iron disks and half-disks. The pattern of the parapet of the side girders was regular and harmonious to the eye (Figure 4).

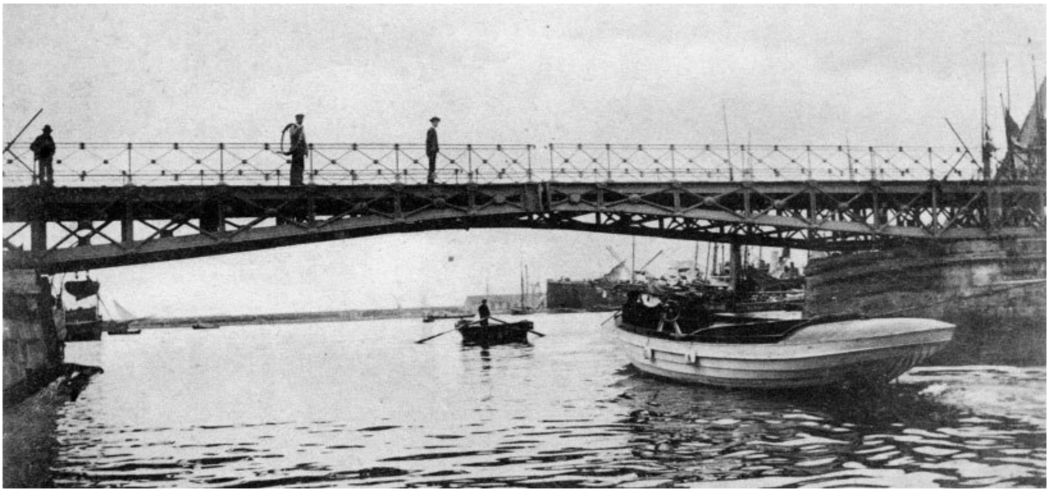


Figure 4. Swing bridge of Livorno that controlled the canal between the harbor and the dockyards (Soranzo Postcard 1902).

The wooden deck was characterised by three overlapping planks. Above the abutments, two fly-wheels fixed to the parapet transferred the movement to the cogged wheels of the pins. The rotation system was designed to be controlled by a single operator and took one minute to complete. In order to allow for the movement of the spans, it was necessary to release the two clamping keys: the first placed on the crown and the second at the end of the abutments.

The swing bridge of Livorno's dockyards was inaugurated in 1868, the same year in which the National Naval Academy was established in the city and remained in service until the early 20th century.

2.2 *The La Spezia swing bridge*

The Gulf of La Spezia, which formed "the most beautiful port in the universe" according to Napoleon, has been the site for two dockyard construction projects since the time of the French government at the beginning of the 19th century. The first project was designed by Colonel Domenico Sauli, at the request of a commission chaired by Admiral D'Arcollieres; the second by the English engineer James Meadows Rendel in 1853 at the request of Camillo Cavour, head of the government of the Kingdom of Sardinia at that time.

Both projects identified the location near the promontories next to the Lazzaretto del Varignano for the navy yard site (Alderotti 2005). In 1860, this idea was rejected in the plan designed by Domenico Chiodo, a Military Engineer Major. In order to guarantee the necessary space for the dockyards, he chose an area close to the town of La Spezia (Calderai 1871).

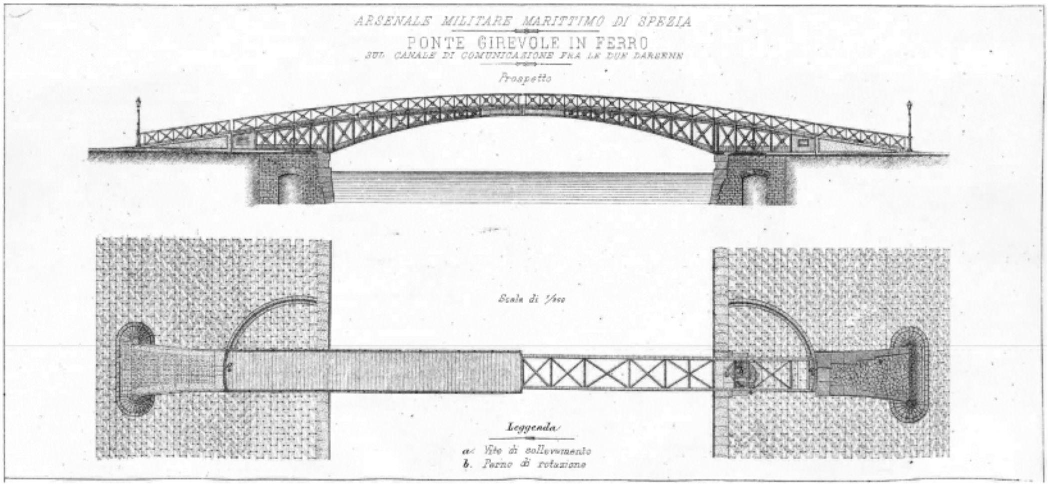
In July 1861, law n.136 established the construction of the dockyard to be arranged in two docks, with four dry-docks, nine construction yards, buildings for management, offices, warehouses and workshops, as well as an area included into the outer limit in order to host future extensions. The La Spezia plant was not fully completed on the date of the inauguration in August 1869, and the works, including the construction of an iron swing bridge over the canal linking the two docks, continued until 1881 (Nascé & Zorgno 1994).

This swing bridge was not the only one in La Spezia; another mobile bridge had already been built at the entrance to the pits intended for the underwater conservation of timber (Galuppini 1969).

The second swing bridge was built after 1871 by the Guppy & C, which had already supplied and installed the mechanisms for draining the dry-docks in 1869–1870.

The bridge was designed by Officer Gio Batta Grassi who chose the double pin scheme, with two turning spans 23 meters long; each turning span had a cantilevered part, 17.20 meters long, and a back end, 5.80 meters long (Figure 5).

The iron bridge was 3 meters wide. Each back end rested on a cast iron platform, which allowed two consequential movements: the lifting and inclination of the turning spans and afterwards, their rotation and alignment to the banks. This sequence of movements was enabled by a pin that was positioned 2.20 meters rearward of the channel border; a screw allowed the initial inclination motion and was controlled from ground level using a special crank placed close to a track that hosted two of the four iron spheres introduced to permit the rotating mechanism. The other two spheres were inserted into an internal track next to the pin. When the bridge was closed, it rested on four bearings; two near the connection between the horizontal and curved lower chords of the turning spans; the others placed on the external track. The movement of each part was allowed by a system of gears consisting of two wheels and three sprockets; in particular by one of the sprockets meshed with a circular ferrule affixed to the ground. Each back end was equipped with a case made of iron sheets, which was filled up with ballast in cast iron blocks in order to ensure the balance of each turning span was shaped as a semi-arch. As with the Livorno bridge, handling was incredibly



Figures 5 and 6. Swing bridge of La Spezia built in the 1870s: the double low arch defined in the drawings above and the bridge in its closed configuration below (Comitato delle Armi di Artiglieria e Genio 1881 – Archive of the Military Engineers of the Navy).

easy, requiring the intervention of a single worker and similarly taking just a minute to complete the operation (Comitato delle Armi di Artiglieria e Genio 1881).

The structure of each turning span was composed of two lateral trusses, with upper and lower chords shaped as two eccentric arches in order to configure the bridge with a profile that progressively tapered from the banks to its centre; in this way enabling the guarantee of a rise of 4.60 meters, permitting the passage of small boats, even when the bridge was closed (Figure 6).

The two trusses were interconnected by horizontal and internal diagonal members. The series of vertical members of trusses was interrupted in the middle of the bridge by the insertion of longitudinal plates that joined lower and upper chords. The deck was made of pine boards, fixed to the iron members with rag-bolts. The iron bridge parapets reproduced the same pattern as the trusses. The two back ends were connected to the ground through two masonry ramps.

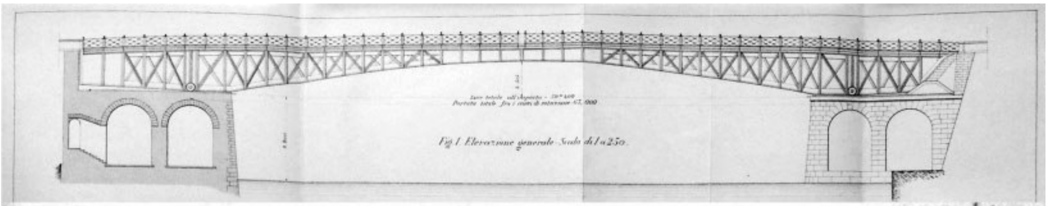
The bridge was widened in 1892 and subsequently replaced in 1914 when the Savigliano Company built a new connection with a longer span situated in a different position.

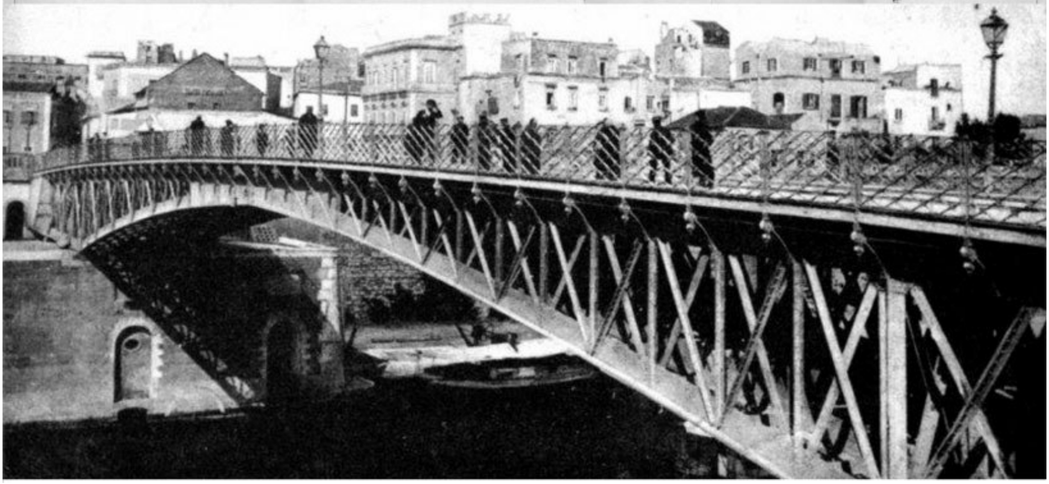
2.3 *The Taranto swing bridge*

The construction of the Suez Canal signalled a turning point in the urban development of Taranto and relaunched its international role thanks to the feasibility of hosting a commercial harbour and an important naval base. In 1865, the government recognized the city as being strategic for the surveillance of the southern coasts. It provided for an extensive program of improvements which included the inner harbour, the Cala Santa Lucia dockyards, the arrangement of the navigable canal and the construction of the new bridge, already proposed in the urban plan of 1861. In 1874, the enlargement of the Canal and the final decision on the bridge location involved the demolition of several historic buildings (Porsia & Scipioni 1989).

Both the design of the iron swing bridge and its construction were put out to tender overseen by the administration of the Military Engineers. The tender call prescribed: the compatibility of the bridge to the existing masonry abutments, and the cantilever of the turning spans back ends, which could not exceed the pivot by more than 11 meters. The width of the deck was 4.70 meters and with sidewalks 1 meter wide for pedestrians. They used a bridge built in Havre in 1861 as a reference model but, further indications concerned the movement mechanism which, within a maximum time of three minutes, had to guarantee the opening and closing of the turning spans (Messina 1888).

Only two companies were invited to submit to the tender, Guppy & C. and the Italian Industrial





Figures 7 and 8. Swing bridge of Taranto, inaugurated in 1887: the pins placed 67 meters apart in the drawing above and the passage of people on the turning spans below (Crugnola 1888 – Postcard, unknown publisher 1910s).

Company of Metal Construction, which was finally awarded the contract. The first proposal was for a mechanism actioned through "driving machines powered by compressed air at high pressure in cylindrical tanks". Collaboration with Eng. Giuseppe Messina, director of works, and the Military Administration, led to the choice of hydraulic turbines placed inside the abutments (Crugnola 1887).

The 89-meter-long bridge turned on two pins 67 meters apart (Figure 7). The iron structure was divided into "two independent parts" which covered a span of 59.40 meters and had a back end that was 11 meters long. Each turning span consisted of four girders placed at a distance of 2.50 meters in the centre and 5.50 meters on their sides. The iron truss structure involved the use of I shaped elements composed of different profiles for the chords, vertical and diagonal members (Figure 8). The trusses ended with regular beams close to the apex of the arch, which was defined by the turning spans. For the chords, I shaped beams with flanges of different width were used: the upper chords followed a parabolic curve reaching a rise of 1.10 meters; the lower chords, horizontal in correspondence to the abutments, were shaped with a semi-circular arch in the cantilevered parts that amounted to a rise of 3.39 meters. Cross diagonal braces were fixed between vertical members along the ladder and between girders. The turning spans were completed on their sides by a series of iron shelves with a 60 cm cantilever placed according to the vertical member that supported the parapet. The wooden deck was built of oak joists placed in the direction of the girders and thick planks running in the same direction as the girders before thick planks arranged in a herringbone pattern were placed on top (Carughi 2003).

The movement system included two subsequent phases. The first disconnected the turning spans and consisted of a small lifting device. The second defined the rotation of the parts. The weight of the bridge was over 1,014 tons. 540 tons of this was the counterweight built of big iron caissons filled with rubble and cast iron blocks (Figure 9).

The bridge was supported by several "rollers and wheels" and pins laid on a triple bearing system that allowed it to rotate. A central cast iron hinge with a diameter of 1.7 meters was radially equipped with truncated cone rollers and bore the weight of the turning span in the raising movement that disconnected the two parts. A cast iron wheel with a diameter of 10.00 meters, supported the rotation of the spans and collaborated with two other cast iron wheels and a steel shaft, placed horizontally, that also allowed the upward movement. A circular rail with a radius of 10.00 meters guided the driving wheels on the abutments in the rotation phase. The IICM started the construction of the cast iron and iron components in the Naples manufacturing workshops at the end of 1884, after which they were moved to Taranto in March 1886. In just three months, the two turning spans were assembled. In July, the wooden deck was also completed. The rotation of the parts was tested in January of the following

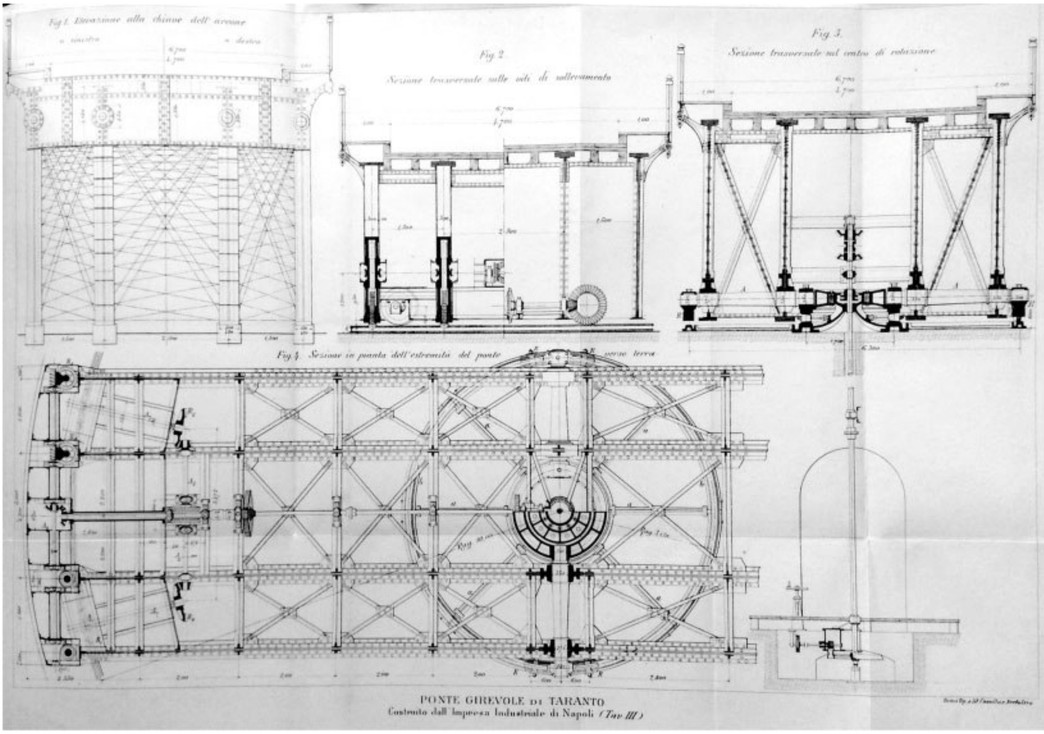


Figure 9. Construction details of the swing bridge of Taranto and sections of the turning mechanism (Crugnola 1888).

year and the bridge was finally inaugurated on May 22nd, 1887.

Since the 1920s, a refurbishment was foreseen but the bridge was replaced only after the Second World War. This replacement bridge was designed by the Technical Office of the Savigliano Company and built by local dockyards in 1958.

3 CONCLUSION

The construction of the Navy's swing bridges represents an epitome of the spirit of the age in the young nation, a 19th century Zeitgeist still uncertain but also vibrant enough to face the technological challenges of a late industrial revolution.

Italian progress in the field of construction techniques and practices was also improving in the effort to bridge the gap with the European countries able to boast of innovations in the fields of mechanical engineering and iron construction. It is no coincidence that the models inspiring Italian examples always came from the most advanced contexts in Europe. Although Italian industry never surpassed this, they managed to advance their technological know-how.

The swing bridges represented an engineering theme that was linked to really fertile research; its importance was undoubtedly related to experiments in the military sector then transferred to the infrastructural equipment needed by the armed forces. As a consequence, the transformative processes which involved the above case studies were the outcomes of coherent research that addressed the search for adequate solutions to the necessary technological progress required by the national war industry. Within these dynamics, "the red thread" which links the case studies is iron construction and the full exhibition of its mechanical and industrial nature. This aspect can also be found in the technical progress experienced in shipbuilding in the same years that affirmed the close original relationship between iron and water.

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