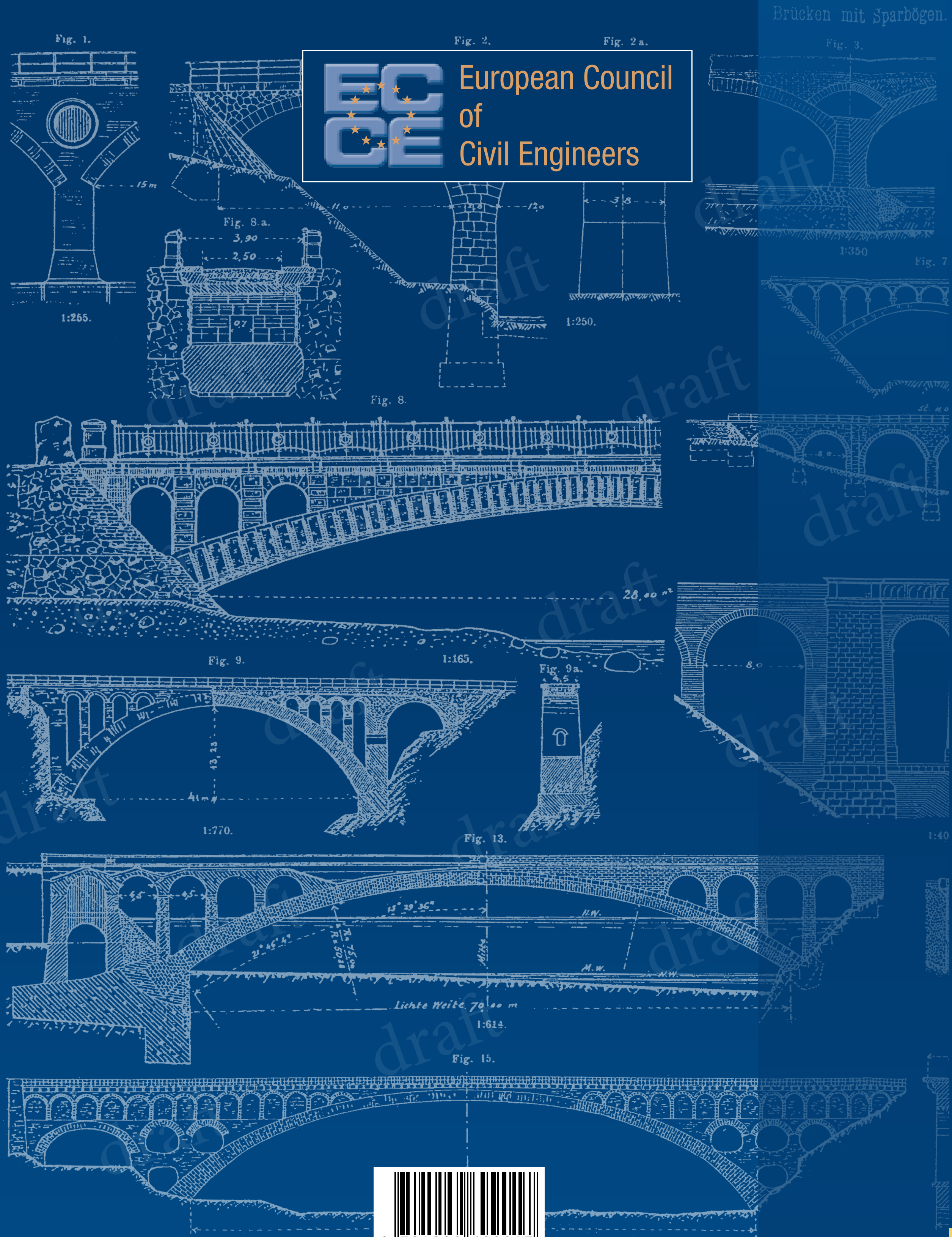

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Notes on the history of civil engineering Volume II

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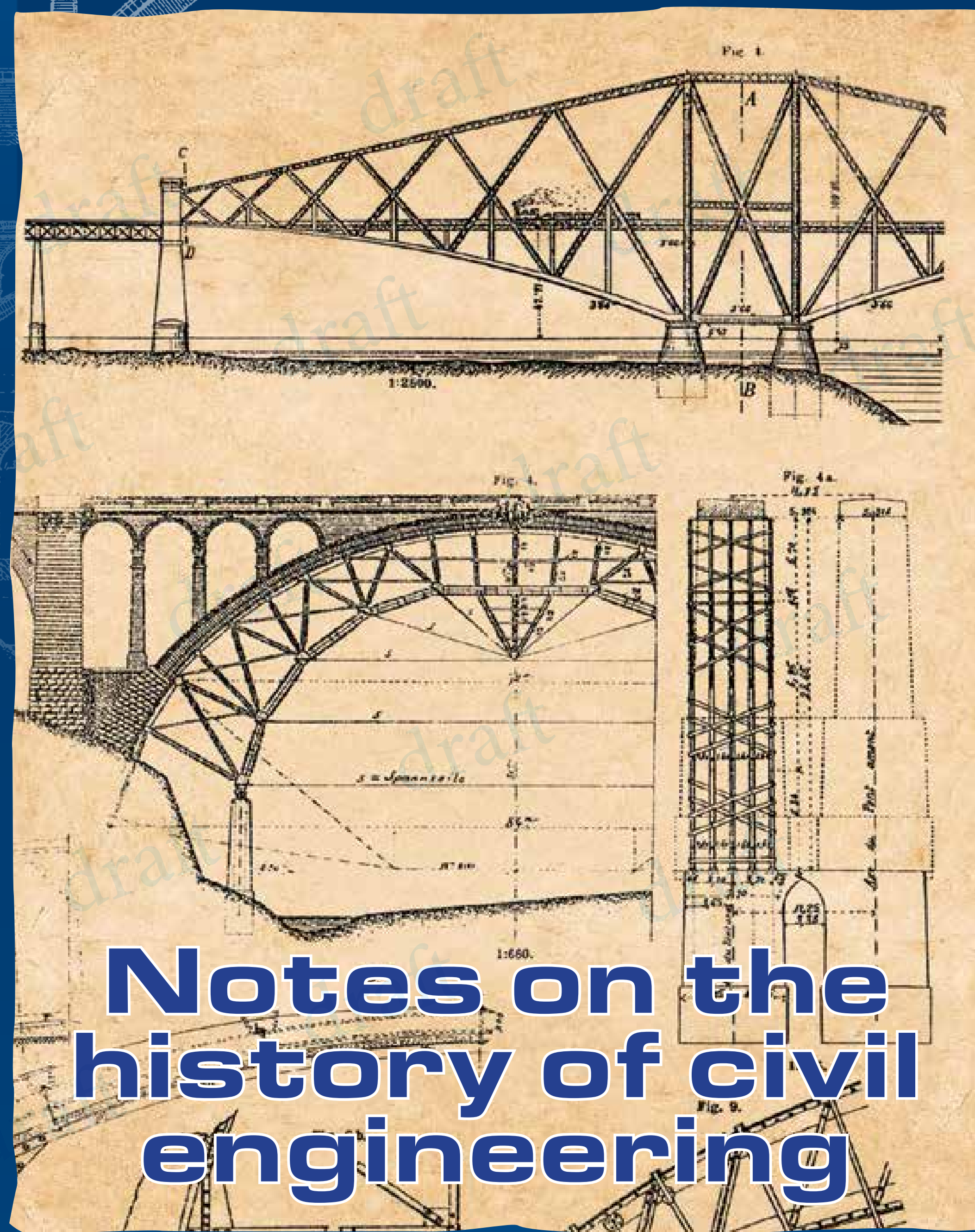

Notes on the history of civil engineering

Volume II

European Council of Civil Engineers

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Volume II

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Content

Jefferson'plaque (photo JF Coste)

Obelisk erected in memory of Pierre-Paul Riquet (photo VNF)

During the dry season, the canal serves also as a reservoir for agriculture. This is one of the fundamental roles of the canal and one of the reasons for its maintenance by the State, since the end of commercial traffic. The canal can irrigate up to 40 000 hectares of agricultural land.

The Canal du Midi represented a modern engineering marvel at the time, originating from the mastery of hydraulic civil engineering. It was considered as the largest public works construction project in Europe of its time, since the fall of the Roman Empire. In 1787 Thomas Jefferson, United States Ambassador to France and future president of United States, visited the Canal. He envisaged the construction of a similar work to link the Potomac River to Lake Erie. In 1825 – 1827, an obelisk was erected on the threshold of Naurouze, by the heirs of Pierre-Paul Riquet in his honour.

The Canal was classified under the French law as a *Grand Site of France* and was inscribed as a UNESCO World Heritage Site in 1996. It has been nominated in 2016, as International Civil Engineering Landmark by the American Society of Civil Engineers – ASCE. To this end, ASCE posed a commemorative plaque on the wall surrounding the obelisk of Pierre Paul Riquet in collaboration with the Société des Ingénieurs et Scientifiques de France - IESF and with the support of Voies Navigables de France.

Some views on historical civil engineering training in France

Jean-Louis Durville, Georges Pilot
Ingénieurs et Scientifiques de France

France has a long tradition in Civil Engineering. In the old times, the French Kings already considered that the country should benefit from the infrastructure development. At the end of the 18th and in the beginning of the 19th century, the progress in the techniques accelerated and the need to train high level engineers lead to the founding of some Engineering High Schools .

In this document, two Engineering Highschools are presented, among the most prominent of them : Ecole Nationale des Ponts et Chaussées, founded in 1747, and Ecole centrale des Arts et Manufactures, created in 1829. As a reference, the careers of some famous civil engineers are presented, as well as their most outstanding achievements.

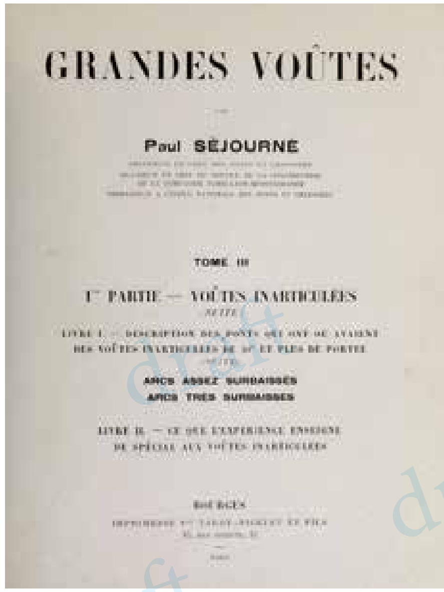
Civil Engineers from French École Nationale des Ponts et Chaussées

In 1747, under the reign of King Louis XV, the École Royale des Ponts et Chaussées (Royal School for Bridge and Road Engineering) was founded and Jean-Rodolphe Perronet became its first director. The school was thought to train the engineers of the Corps des Ponts et Chaussées which had been set up in 1716: these engineers had to ensure the technical quality of the construction and the maintenance of the roads and bridges in the French kingdom, while being concerned with public finances.

During the 18th century, the Ecole des Ponts et Chaussées (ENPC) trained from 15 to 45 engineers every year. They were driven by public service passion, they were convinced of the superiority of reason, they were believing that tracks and roads are fundamental to the economy of the Nation. More and more topics were being taught at ENPC: harbour and coastal defence, canals, locks, etc.The École Polytechnique was founded during the French Revolution. Napoleon the 1st made this school the training center of the scientific and military elites, and ENPC was assigned the mission to specialize some of them in the field of the civil engineering.

ENPC had high-level professors, such as Henri Navier, Paul Séjourné or Albert Caquot, who trained great engineers and also scientists in the 19th and 20th centuries, such as Adhémar Barré de Saint-Venant, Eugène Belgrand, Jean-Baptiste Biot, Augustin-Louis Cauchy, Gaspard-Gustave Coriolis, Jules Dupuit, Henry Darcy, Augustin Fresnel, Joseph-Louis Gay-Lussac, Louis Vicat, etc. All of them contributed to elaborate a significant body of scientific and technological work (elasticity and plasticity of steel or masonry, new materials as cement or concrete) that could be applied directly by engineers. The Ingénieurs des Ponts et Chaussées played a central role in the country expansion, modernizing the roads, developing the railway network, expanding urban water supply systems, etc.

In the 20th century, ENPC was training engineers who will enter the service of Government,


GRANDES VOÛTES

Paul SÉJOURNÉ

TOME III

1re PARTIE — VOÛTES INARTICULÉES

ARCS ASSEZ SURBAISSÉS
ARCS TRÈS SURBAISSÉS

BOURGES

Figure 1: First page of volume III from Séjourné's book

but also who will join private companies. ENPC has progressively increased the diversification of its education supply: civil engineering (roads, bridges, buildings, energy), city and land planning, mechanics and construction material, fluvial and marine hydraulics, transportation systems, environmental economics, etc.

ENPC has an important library dedicated to works of the past (https://patrimoine.enpc.fr/): maps, plans and sections of bridges sections, drawings from the students, etc.

Paul Séjourné (1851-1939)

P. Séjourné graduated from École Polytechnique and ENPC. He began his career with the French Administration, as a civil engineer responsible for various types of infrastructure, bridges and railway lines.

He joined the Fives-Lille company in 1890, and then the railway company Paris-Lyon-Méditerranée

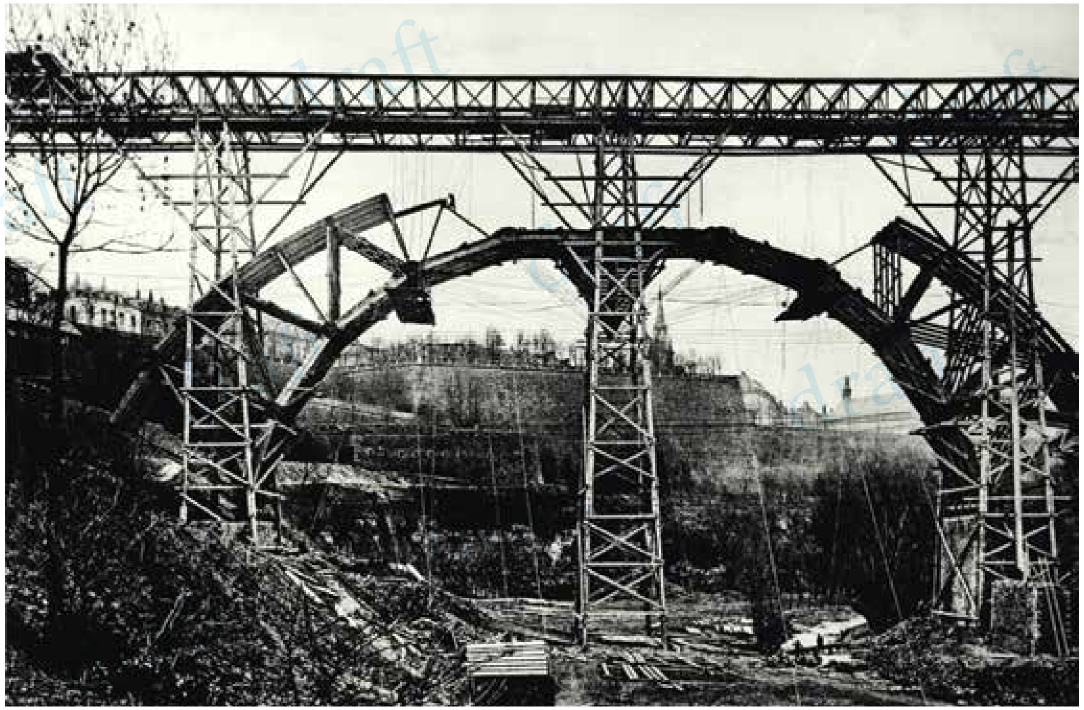


Figure 2: Adolphe bridge under construction at Luxembourg town (Photograph by Charles Benrhoeft)

(PLM) where he supervised the construction of bridges and tunnels. He became a member of the executive board in 1919.

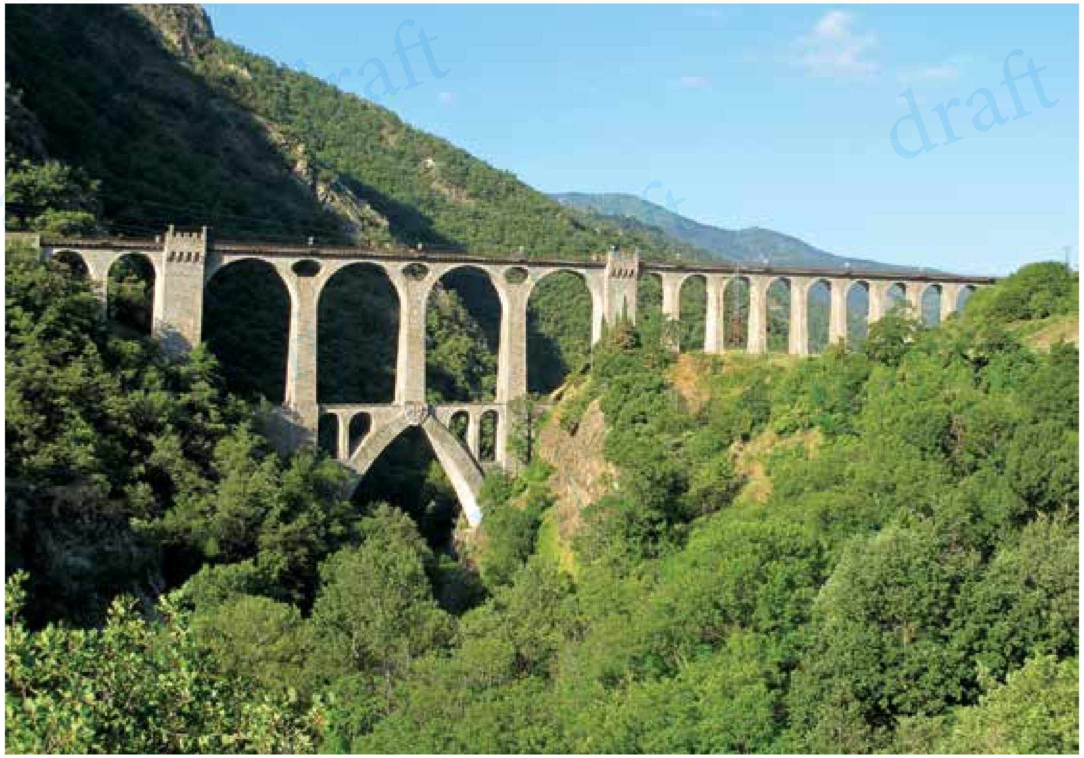
P. Séjourné published in 1913-1916 his six-volume work Grandes Voûtes (Large Vaults), an exhaustive book about stone bridges (Fig. 1).

Adolphe Bridge at Luxembourg town (Fig. 2) is a large stone bridge with an 84,65 m span, a record at that time. It consists of two parallel stone arches, 6 m apart, supporting a reinforced concrete roadway. Grand duke Adolphe laid its cornerstone in 1900.

The Fontpédrouse railway bridge (Pyrénées-Orientales, France) was completed in 1908. Granite stones were used in the arch and in the piers, and reinforced concrete for the deck. It is 237 m long and the span of the ogival arch is 30 m (Fig. 3).

Paul Séjourné

Figure 3: Fontpédrouse bridge (Pyrénées-Orientales) (photo J-L Durville)



The importance of the tower today

Today the Eiffel Tower is Paris's most profitable attraction. Despite its high running costs, it returns an annual profit of around €18 million. In 2018 a three-metre-high bulletproof glass barrier was erected around the tower as a security measure. This barrier is also designed to protect the area around the tower from vehicle ramming attacks from the direction of the nearby bridge. The cost of the barrier was around €30 million. As the 2024 Olympic Games approach, the Eiffel Tower will be further rejuvenated by numerous interventions and improvements that are already under way.

There is no denying that the Eiffel Tower is today an icon of Paris, and that it is no longer possible to imagine Paris without the Eiffel Tower. It has become an essential part of the Parisian panorama and is very probably the most photographed object in Paris. Yet it would be wrong merely to treat the tower as a top tourist attraction and a vantage point for a wonderful view of Paris. Above all, the Eiffel Tower is an outstanding technical monument and a tribute to the remarkably high level of (French) engineering skill at the end of the nineteenth century.

The first floor of the tower Photo: G. Humar

Contribution of Civil Engineers to the Early Modern Architecture of Latvia

Photos by the author, unless stated otherwise

Jānis Krastiņš, Dr. habil. arch.,
Professor, Full member of Latvian Academy of Sciences

The beginning of the 20th century marked a massive economic boom and subsequent construction throughout Latvia. This period also witnessed significant innovations both in terms of the artistic and stylistic development of architecture, structural and technical design of buildings and their construction technologies. Art Nouveau emerged in architecture, giving rise to the system of modern architectural styles. This style is based on the reflection of spatial structure and structural design in the artistic shape of buildings, alongside the use of new materials, framework, and long-span floor structures. Riga's architecture was completely dominated by Art Nouveau. Riga is the most impressive city in Europe in terms of its number of Art Nouveau buildings. These buildings were the main reason for including the entire central part of the city, with an area of about 430 ha, on the List of World Heritage Sites in 1997. The city of Liepāja also features an impressive range of Art Nouveau buildings.

Most of the construction designs were developed by architects, although civil engineers often dealt with architectural tasks. Most Art Nouveau buildings in Riga are quite splendid and artistically sophisticated, yet at the same time embody rationality and modest elegance. The formal variety of this style is dominated by so-called perpendicular Art Nouveau and National Romanticism. There are also a few extensively decorated buildings with eclectical elements and facades boldly covered with ornaments and sculptural decorations made in the ornamental language of Art Nouveau. More than 10 such buildings were erected to the designs made by civil engineer Mikhail Eisenstein (born *Moisey Aisenstein*, 1867–1920). After graduating from the St. Petersburg Institute of Civil Engineers in 1893, he was appointed as a civil engineer to the National Real Estate Supervisory Authority in the Baltic States and moved to Riga. He was also interested in arts and history. Between 1900 and 1902, he completed a study programme at the St. Petersburg Institute of Archaeology and later became a staff member of this educational institution; in 1917, he was appointed to the Institute's Union Council[1]. He was a passionate art collector and brought many items from Paris, London, Rome, and Madrid. In 1918, due to political turmoil, he was forced to leave Riga where he left his unpublished scientific research *Historical Materials of Vidzeme Governorate*[2]. Architectural work alongside his other duties was one of his diverse artistic expressions.

The first biggest architectural creation by Eisenstein was the J. Lazdiņš's apartment building at Elizabetes iela 33 (1901). The rich, baroque style eclectic facade of the building (Figure 1) also contains some Art Nouveau ornamental elements – various masks, geometric circles, and bundles of vertical lines of different length, while the glamorous entrance hall (Figure 2) is decorated in pure

1 **Соколов, Р., Сухорукова, А.** Новые данные о предках Сергея Михайловича Эйзенштейна. *Киноведческие записки,* 2013, № 102/103, стр. 320. [New Data on the Ancestors of Sergei Mikhailovich Eisenstein. *Cinematographic Notes*].

2 Op. cit., стр. 321.

Figure 1. Riga. Apartment building at Elizabetes iela 33. 1901. M. Eisenstein

Figure 3. Riga. Alberta Street. A postcard from the early 20th century

Art Nouveau style featuring appealing iconic ornaments. It incorporates masks, sinuous lines, floral motifs, and compositions of geometric figures, as well as three vertical lines, with the middle one being longer than the others. This ornamental pattern can be found in Art Nouveau buildings throughout Europe – from Helsinki to Lisbon, and Budapest to Brussels.

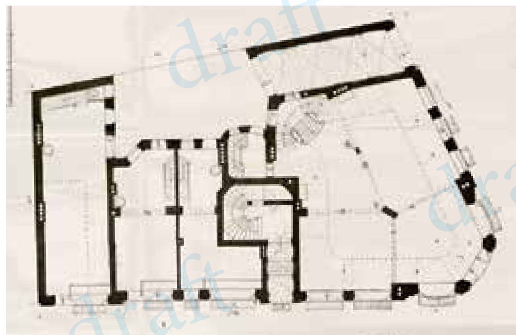
Soon after, Eisenstein started his theatrical display of Art Nouveau in Alberta iela (Figure 3), where within three years several buildings designed by him were erected along the street, namely, buildings No. 8 (1903), No. 6 and No. 4 (both in 1904), No. 2 and No. 2a (both in 1906). The facades of all these buildings resemble splendid decorations, literally crammed with many different unconventional ornamental elements – intertwining floral motifs, masks, different sculptural elements, medusas, sphinxes, lions, snakes, dragons, and other monsters, as well as covered with curved and straight lines, circles, and other geometric shapes. Faces of masks are contemplative, sneering or screaming in fear and holding their heads in their hands. In terms of artistic creativity, the most outstanding building is the one at Alber-

Figure 2. Riga. Entrance, apartment building at Elizabetes iela 33. 1901. M. Eisenstein

Figure 19 and 20. Liepāja. Kalpaks Bridge. 1904–1906. H. Hall

in the archives of his descendants' family. There were shops on the first two floors of the building. In the left wing, behind high shop windows, they were arranged in full height of both floors, with a wide balcony in the back that could be reached by internal stairs. In the largest shop located in the corner of the building, the balcony fully surrounded the shopping hall around its perimeter, leaving a high, atrium-like space in the middle. The balcony was accessible via the monumental stairs which also led to the basement from the ground floor. During the Soviet era, this building was used by a specialised trade company for military service. In the 1990s, the premises were occupied by a bank, which completely destroyed the unique interior architecture. On the third and fourth floors, there are still large and modern apartments. They can be reached by spatially impressive winding stairs. A bathroom in a five-bedroom apartment was located in the back part of the apartment next to the bedrooms. This was an innovative solution at that time that was not used more widely until the 1970s.

The spatial structure of the building is accurately reflected in the facade architecture, which appeals with its rich ornamental finish. The facades reveal a whole collection of various ornamental reliefs arranged in a dense layer. They include geometric shapes and figures – rhombs, triangles, circles, spirals, cones, and pyramids, as well as flowers, ribbons, wreaths, festoons, glamorous ornamental friezes, stylised palmettes and many more. At the entrance, visitors are greeted on both



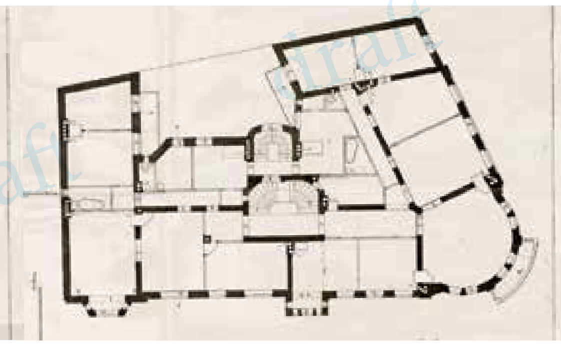


Figure 22–26. Liepāja. Apartment building with shops at Graudu iela 44. 1908–1909. Ch. Carr. *Front view, facade design drawing, first (ground) floor plan and upper floor plan*

Valleta - Grand Harbour

The Civil Engineering Profession in Malta

Dr. Perit Jeanette M Muñoz Abela, Prof. Alex Torpiano
on behalf of the Kamra tal-Periti, Malta

While in the rest of Europe, the trend lies towards the separation of architecture and engineering, the architect-engineer in Malta may at a first glance seem rather odd. The idea of a single person exercising the dual role of architectural designer and civil engineer is one of the main constants in the history of the profession in Malta perhaps mainly due to the result of the restricted economy of an insular society which was, and still is, numerically small, intensely practical and conservative in its everyday building needs. Hence, the terms "mastru" (master), "mghallem" and "perit" (both meaning knowledgeable or expert, the former of semitic, and the latter of latin, origin) were interchangeably used to indicate this role in construction.

The initial installation of the military Order of St John in Malta in 1530 brought about three important changes in the Maltese settlement patterns:

- Firstly the foundation and the subsequent development of a number of new towns and fortresses
- Secondly the rapid development of a number of large inland towns coupled with the parallel 'extinction' process of the older medieval hamlets
- Thirdly, the very persistent reluctance of the civil population to occupy the coastal zones in the northern part of the island which were considered to be vulnerable to Turkish raids

As one would expect, these changes in the settlement pattern immediately generated a large building boom which gave the opportunity to a number of Maltese master-masons to design several dwelling blocks and churches in the new developing villages. Here, the activity of these buildings experts or 'periti,' as they were commonly called, was largely uncontrolled by the Order's administration which allowed them to design any new building and supervise the works, so long as the new structures were not of a military nature.

Harbour cities, however, were dealt with differently because at these locations there was the need to relate carefully the civil buildings with the new network of fortifications which was aimed at defending the Grand Harbour. Since the Maltese periti were inexperienced in the refined techniques of fortification, they were allowed to have an advisory rather than a decision-making role. Their respect from the Knights was based on their precise knowledge of local materials and methods and for their experience in handling the various human aspects of the local building industry. Because of this they were included within the framework of the Order's administration by being asked to attend a special board known as the 'OFFICIUM COMMISSARIORUM DOMORUM'. This was the planning control body which shaped much of the urban growth which took place in Malta.

Besides the frequent meetings of the Commission, the 16th century gave the Maltese periti the opportunity to come into contact with the several foreign military architects and engineers like Laparelli, Genga, Ferramolino and others whom the Knights invited to Malta to act as con-

Girolamo Cassar (1520-1592)

sultants in the design of their fortifications and public buildings. Thus, for the first time, the Maltese periti found themselves interposed between the 'high' architectural concepts of the foreign engineers of the Order on one hand and the vernacular architecture of the Maltese mediaeval builders on the other. It is to their credit that they contributed to both traditions, for by their expertise of local materials and building methods they made it possible for the masters to execute their grand paper designs for palaces and fortifications, while in return they channelled certain traits of the imported 'high' architecture into the vernacular tradition which started developing along new lines. In this way, the Maltese architect-engineers of the 16th century consciously or unconsciously managed to introduce new building ideas into Malta with the result that a new popular style emerged and the foundations for future development were securely laid.

Apart from bringing the Maltese periti into close contact with the foreign masters who from time to time came over to Malta, the coming of the Knights also influenced the local profession in three other aspects.

Grandmaster's Palace 1571

- The Knights introduced the idea that in Malta, where civil architecture was closely linked with the fortifications network and the water supply system, it was ideal to have professional people with a thorough know-how in both architectural design and civil engineering. Thus, the birth of the concept of the Maltese architect-engineer (this was quite common in the Renaissance and the Baroque period throughout Europe and remained the norm until the emergence of the civil engineer).
- The Knights instilled an element of organization which the building profession in Malta so far had lacked — an organization which was subsequently elaborated to control all building in Malta.
- The Knights provided incentive for the Maltese periti to widen their knowledge on building method and design through a system of patronage through which promising Maltese periti like Cassar and Gafà were sent abroad to receive formal academic training.

Lorenzo Gafà (1639-1703)

Mdina Cathedral 1697.

Mihael Štrukelj

1851 - Log pod Mangartom, Slovenia
1923 - Helsinki, Finland

Mihael Štrukelj, Michael Strukel, Mikael Strukel

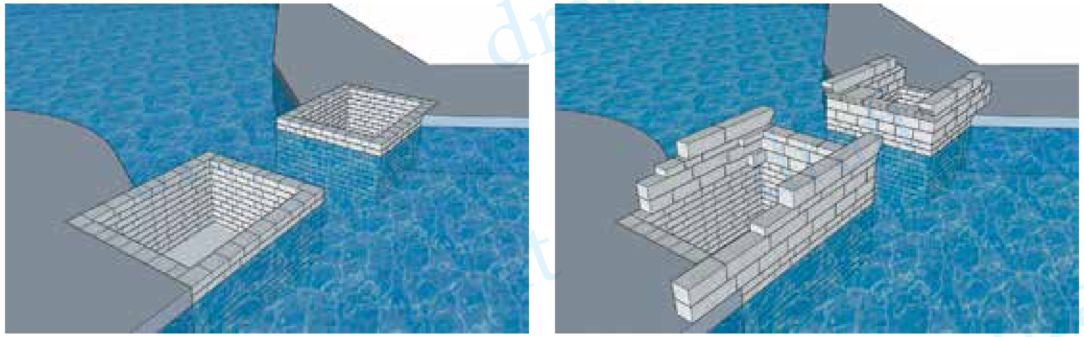
A civil engineer of worldwide renown and the first Slovene to be appointed a professor of civil engineering at a university

Introduction

Štrukelj or Strukel?

Which version is correct? If we are talking about "Mihael Štrukelj" as a fellow Slovene who happened to spend most of his life in Finland, then this is the right version to use. But if we are talking about the internationally recognised civil engineering expert from Finland, we should refer to him as "Michael Strukel" or indeed "Professor Michael Strukel". Why? Because this is how he signed his name and was officially known in Finland. This is how he presented himself as the author of the books he wrote. Although to be even more precise, the name that actually appeared on his books and in the introductions to them was simply "M. Strukel". How do we explain such modesty? Perhaps his exclusive use of the form "M. Strukel" was because the Finns knew him as "Mikael Strukel". This is also how his name appears on his grave in Helsinki's Hietaniemi Cemetery. When talking

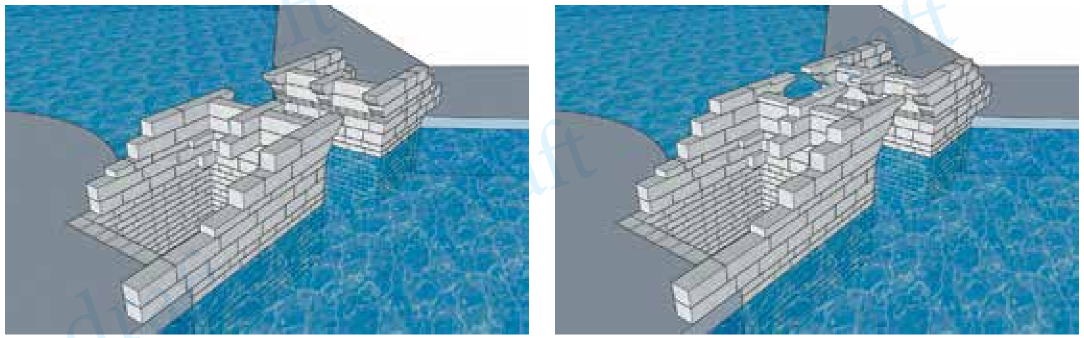
Log pod Mangartom, Slovenia *Photograph by Bogdan Kladnik* zontal stone supporting elements was represented by the stability of the individual components that were at the same time the load-bearing elements of the bridge, and the global stability of the bridge structure as a whole. This is the reason why the distribution of the position and weight of the individual load-bearing components of the bridge had to be very well thought out in order to ensure sufficient stability of the bridge structure at all possible loads.



Foundations of the draw bridge

The secret of the inner structure of the bridge

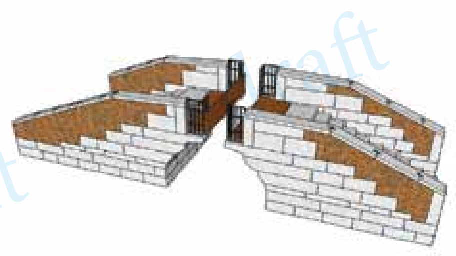
From the two photographs available when research into the bridge's structure was being carried out – believed to be the only two surviving photographs – it is possible to identify above all the bridge's external structure. But what structural elements are concealed in its interior? Detailed study of the two photographs revealed that a further supporting system, consisting of stone supporting elements placed horizontally one above the other in a triple layer, was also present in the middle of the bridge structure. This discovery made the rest of the internal structure of the bridge considerably clearer. The last secrets of the bridge's internal load-bearing structure were explained and, through the use of computer graphics, it became possible to reproduce and present the entire structure of the bridge with a good degree of reliability.



Internal structure of the bridge

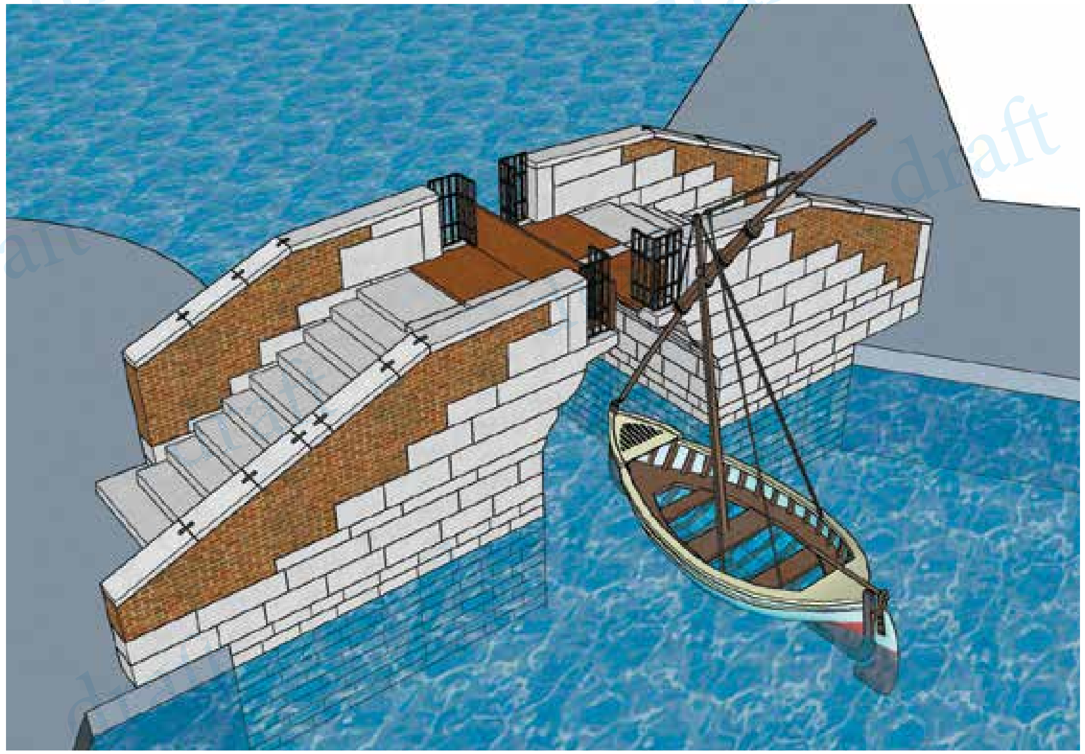
The lifting mechanism and the passage of vessels below the bridge

Because the two halves of the bridge were entirely independent and physically separate from each other, crossing from one side of the bridge to the other was facilitated by a light wooden deck structure positioned so as to bridge the gap between the two separate parts of the bridge. The opening at the top of the bridge that facilitated the passage of the masts of the vessels passing below the bridge was between 70 and 80 cm wide. A simple chain mechanism allowed the wooden deck to be raised into a vertical position, thus allowing vessels with tall masts to pass under the bridge.

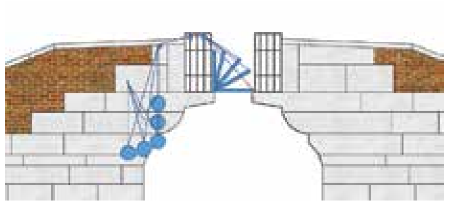


Opening on the top of the bridge

The two surviving photographs of the bridge reveal that a system of weights on a chain was employed to facilitate the raising of the bridge's wooden deck structure. The raising of this section into a vertical position was arranged in such a way that a single sailor could raise the deck without any particular effort and in this way open the passage beneath the bridge. The raising mechanism would, of course, have undergone rigorous testing before being put into service. It would also



Ship with a mast entering in the interiour harbour



To model the movable parts of the bridge, the deck and the movable section of railing, we used special dynamic components that can be opened and closed interactively. In this way we were able to simulate the opening of the bridge and the passage of sailing vessels through it. We also carried out an accurate study of the opening mechanism, consisting of weights and chains, that allowed a sailor on board a vessel to raise the solid wooden deck of the bridge using a boat hook or gaff and close it again after the vessel had passed under the bridge.

Finally, we focused on the virtual placement of the digital model in real space, using a special hybrid technique known as mixed reality (MR) that merges reality and virtual reality. To do this, we first had to orient a device (in our case a smartphone) in real space using a special program, after which we inserted our digital model of the bridge into this digitally rendered space at actual size. Having inserted the bridge into its original position as accurately as possible, we then walked all around it. The result was the recording that you can see online at https://bit.ly/piranskimost.

The digital model of the Piran bridge could also be used for other purposes: we could print it on any scale using a 3D printer, enable people to view it in its original location by means of special MR glasses, project it with a 3D holographic projector, or demonstrate a simulation of the raising mechanism.

Please scan the QR code to view the video of the draw bridge made by Danijel Rebolj.

The foregoing study is part of the book "Cuatro siglos de ingeniería española en Ultramar. Siglos XVI-XIX" (Four Centuries of Spanish Engineering Overseas. 16th c. - 19th c.) published by ASICA to mark the 300th anniversary of the first Ordinances of Engineers in Spain dating from 4th July 1718 and an exhibition of the same name that took place in 2018 at the General Archives of the Indies in Seville. ISBN 978-84-09-09682-4 ©ASICA asica@asica.es

Spanish Military Engineers and the engineering models

Horacio Capel Sáez
Professor of Human Geography at the University of Barcelona

No state power has ever been exercised without science and technology. The organization of modern states was not just based on scientific knowledge but, rather, they often contributed to scientific development themselves. This is what happened under the Hispanic Monarchy[1] from the 16th c. onwards. The military and administrative structures, the settlement of the population, the foundation of cities, the organization and mapping of the territory and many other government measures were linked to the state-of-the-art science of the time.

The emergence of new social and intellectual issues had a bearing on the scientific specialization process and the creation of new disciplines. In the debate on the development of scientific thinking, the so-called *externalist* and *internalist* schools of thought were at odds back then. The link between both could stem from the focus on scientific communities and professional corporations. The study of the Corps of Military Engineers and, more broadly, that of the professional engineering corporations, is thus of great interest for understanding the external and internal factors of the development of technical and scientific knowledge.

Military engineers were then a corporation at the service of the State for the tasks of fortification and land planning. The early development of military engineering in Spain was a model scheme and had an impact on the evolution of civil engineering in the 19th c. This development was affected by political, economic and social changes, and its shaping grew out of a number of interactions. In any case, the study of the professions is of great interest as related to the requirements of the State and the Public Administration, as well as the requirements of the economy and society at large.

Military Science and Mathematics

Since the Renaissance there had been State military engineers in Spain, Portugal and other countries. Broadly speaking, they served the State in all its needs, including the intervention in public works, infrastructures and building sites in the wake of an age-old tradition dating back to the times of the Roman Empire, when the military were used as technicians in infrastructure building operations.

1 Or Spanish Empire, since it included both the European and Overseas possessions.

of electric power in Spain, which we have had the opportunity to study, clearly points to this fact. As the building of large hydraulic works for electricity generation began, mobility rose sharply; North American, British and Canadian engineers acted on behalf of the Brazilian Traction and Barcelona Traction companies across both continents, while French technicians acted in Asia, Africa and Europe. From the 1890s, German, British and French investments in this new area also contributed to the cross-border movement of technicians from those countries.

Contemporary engineering fell into various professional profiles, with strong self-awareness and sometimes at odds with each other. Conflicts arose among engineers, and also between engineers and architects and other technicians 19th c. engineers had a strong sense of responsibility, they believed that they should participate in public debates and share their ideas, and made proposals for the reform of urban areas and society as a whole. That's why they were liable to be accused of being visionaries or utopians. The public acknowledgment of engineers' worth both as professionals and individuals contributed to the building of their collective identity.

General Don José de Urrutia y de las Casas. Circa 1798. Painting by Francisco de Goya y Lucientes (1746-1828). Oil on canvas, 199.5 x 134.5 cm. El Prado Museum, Madrid.

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Civil Engineers, technical revolutions

Ignacio Sánchez de Mora y Andrés
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The 19th century was an extremely intense, turbulent and revolutionary period from a technical, political and social point of view. The technological developments, showcased in the widespread use of the steam engine in industrial processes and in the use of new construction materials such as steel, brought about a technical shake-up and a new era in industrial production and infrastructure design. It was, as Engineer Fernando Sáenz Ridruejo rightly puts it, the "queen stage" of public works. Furthermore, at the dawn of the century, the Cuerpo de Ingenieros Caminos y Canales [Corps of Road and Canal Engineers], otherwise known as Civil Engineers was created. It was Engineer Agustín de Betancourt y Molina who set this irreversible process in motion that split the professional activity into military and civil engineers, put in writing in the 1803 Engineers' Ordinances, sponsored by José de Urrutia y de las Casas. Several queries with books point to a complex transition, with a marked shortage of civil engineers and the military technicians' reluctance to hand over their competences. This transition was particularly slow Overseas, due to the intermittent spells of uprisings, wars and attacks by European powers. In the political arena during the 1810s and 1820s, while the Peninsula was fighting the War of Independence[1] against France, multiple Spanish Overseas territories began to cascade into independence, which led to a dramatic downsizing of the Empire estimated at around 12 million square kilometres, or 24 times as much as the territory of present-day Spain. As a key social milestone in the century, we can highlight the first Spanish Constitution, passed in Cadiz in 1812, which set forth the sovereignty of the Spanish people over the Territories. This gave rise to a feeling of shared ownership of the Overseas Provinces, which for centuries had been reserved for the Crown. And this is why the loss of Cuba, Puerto Rico and the Filipinas in 1898 made such a disastrous and lasting impact on Spanish society, which until then had been relatively impervious to the vast losses that had preceded it.

With this setting in mind, we will go on to focus on the history of our admired engineers and their wits. It was in 1802 when Agustín de Betancourt y Molina managed to establish the Escuela del Cuerpo de Ingenieros de Caminos y Canales in Madrid, inspired by the École *des Ponts et Chaussées* in Paris. The gestation was a long one after the intense international academic training of a team of scholarship holders of the King of Spain, among which, besides Betancourt, his col-

1 Hence the name Peninsular War

Spanish engineering in the last Overseas territories

Cuba, Puerto Rico and the Filipinas archipelago were the last territories left in which to apply the improved building techniques of the 19th c. A downsized, weary Empire strived to design major works that should ensure the progress and welfare of the last Overseas provinces. Fortunately for these territories, their growing demands were met with consolidated design techniques.

Although a number of engineers graduated from the Madrid School on a regular basis from 1839 onwards, it failed to fill all the vacancies in the different provinces despite the fact that, since 1866, the Directorate General of Public Works of the Ministry of Overseas offered to double salaries for those who served the State outside the Peninsula. Consequently, military engineers and civil engineers took on the task of meeting the huge demand for infrastructure design.

Map of the western part of the Island of Cuba where Engineer Francisco Lemaur designed the Güines Canal which was finally replaced by the first railway line in Spain opened in 1838. General Archive of the Indies, Seville.

The Very Loyal Island of Cuba

Considered to be the key to the "New World" and the pearl of the Spanish colonies since Christopher Columbus first saw it in 1492, Cuba was home to the ships of the *Carrera de Indias* Fleet[3] from the viceroyalties of Peru and New Spain[4]. In the Great Antilla, which flourished for centuries, remarkable infrastructures were developed and some of them, such as the Vento Canal, designed by Military Engineer Francisco de Albear y Lara for the water supply of La Habana, deserved worldwide recognition for its design, receiving the Gold Medal at the Paris World Exhibition in 1878, where it was considered an engineering masterpiece. In the period 1805- 1898, 21 deputy engineer inspectors followed one another, being Brigadier Francisco Gelabert y Albiñana and Brigadier Carlos Barraquer y Rovira the first and last in the 19th c., respectively.

Throughout the 19th c., railways won the battle against navigation canals, showing that technological innovation always has the upper hand. The steam engine applied to railways put an end to the navigation canals in which the Crown had invested huge amounts of money over the centuries. The infrastructure that best illustrates this fact is the San Julián de los Güines Canal to La Habana, whose plans were finally replaced by the first iron road in Spanish territory, which was opened in 1838 stretching over 46 kilometres, 10 years before the section from Barcelona to Mataró[5] was built.

Thus, the best techniques and knowledge prevailed. The railway was presented as a means of transport closely linked to industry, particularly that of sugar cane, which was blooming and aimed at exports. Efficient intermodality was born. Private companies and capital, attracted by the promising future of the iron roads, risked large amounts hoping for future profits. The public work concession contracts consolidated in the Kingdom. The State rightly granted the concessions and created business fabric. The new means of transport reached such a development level that in 1872 there were 1,355 km in service on the island, plus a few hundred private kilometres that made it possible to transport goods from sugar mills.

Among the infrastructures dedicated to urban supply, besides the aforementioned 11-kilometre-long Vento Channel, whose system included a siphon excavated under the Almendares River bed, and which the La Habana City Council renamed after Albear, its designer and director, mention must be made of the pre-existing Ferdinand VII Aqueduct, which included cast iron pipes, and the Burriel Aqueduct, directed by Engineer Gabriel Faura y Casanelles, which supplied drinking water to the city of Matanzas and became the second largest on the island.

With reference to port and coastal signalling infrastructures, it was in the cenntury that their management was gradually transferred from the Navy to Public Works. For centuries, the faulty signalling on the American coasts had led to countless human and material losses. The ships had to face one-off manoeuvres without previous references that often made them capsize. Fresnel[6] optics came in to revolutionise maritime references and make an invaluable contribution to successful

3 Maritime trade between metropolis and Overseas provinces.

4 The Viceroyalty of New Spain, from the 16th c. - 19th c., was made up of Mexico, Central America, north of Panama, the SW of present-day US, the Philippines and the Spanish West Indies. The West Indies or Spanish Antilles was the collective name for the colonies in the Caribbean. Having been the first lands to be permanently colonized in the Americas, they were also the most enduring part of Spain's American Empire, only being surrendered in 1898 at the end of the Spanish–American War. For over three centuries, Spain controlled a network of ports in the Caribbean including La Habana (Cuba), San Juan (Puerto Rico), Cartagena de Indias (Colombia), Veracruz (Mexico), and Portobelo, (Panama), which were connected by the fleets mentioned above.

5 The first railway line built on the Peninsula.

6 A French engineer des Pontes et Chaussées.

Las islas Filipinas, pearls of the East

The archipelago, made up of more than 7,000 islands, was mapped from 1521 onwards when Ferdinand Magellan landed on its shores in his quest for the Spice Islands and as an intermediate stage in the first voyage around the world, successfully completed by Juan Sebastian Elcano in 1522. Despite how far the islands may seem to contemporary Spanish identity today, from 1565 to 1898 they were part of Spain. There were dozens of engineers who designed infrastructures, the spatial planning and defended the territory. Mateo del Salz was the first military man to act as an engineer in 1565. For the sake of historical data we will say that the fortified compound of the city of Manila was in 1592 under the remote direction of the renowned King's Engineer, Leonardo Turriano, who held the position of Chief Engineer of the Kingdom of Spain during the reign of Philip II. Focusing on the period in question, it was in 1804 when Engineer Ildefonso de Aragón y Abollado reorganized the Engineering Company which would soon be joined by the Manila Workers' Company. During the 19th c., 14 other engineers held the position of Deputy Engineer. In 1863, a *Maestranza* [7] of Engineers was organized for the islands under the Commanding Enginner of the Manila Plaza of the Manila *Plaza*[8]; years later, the staff to fill the positions of Master Builder, Surveyor and Work Assistant for the archipelago were recruited. The first Pilipino railway line connected

The city of Manila with the layout of the tramway lines. 1879. León Moussour; endorsed by Inspector Manuel Ramírez Bazán. National Historical Archive, Madrid.

7 The term refers to people who worked in workshops for construction, repair and maintenance tasks (originally of artillery guns) and offices therein.

8 Here: military site.

Birmingham Water Supply, 1826 - 2019

Engineering Foresight from Hindsight

Birmingham, the second largest city in the United Kingdom, was a mid-sized town in the early eighteenth century. Its location, resources and inventiveness led it to becoming one of the fastest growing UK towns in the late eighteenth/early nineteenth centuries, stimulated by companies like Boulton & Watt who built the largest manufactory in Europe to supply their steam engine components and mill equipment to help power the industrial revolution. Growth of the town from 1770 onwards (Fig. 1) put increasing pressure on the localised water supplies.

After several attempts, Birmingham Waterworks Company was empowered in 1826 to abstract water from the River Tame with the first supplies coming on stream in 1831. It took until 1853 for the supply to be constantly available, but Birmingham became the first town in the UK to

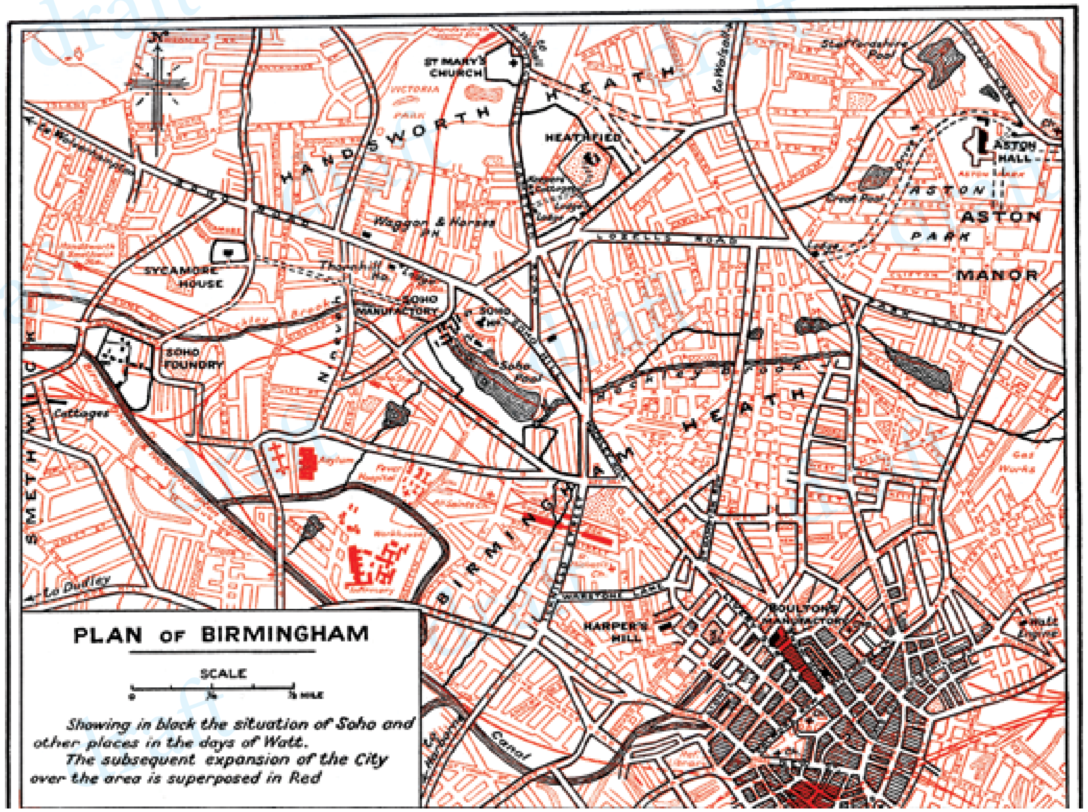

Fig. 1 from Dickinson

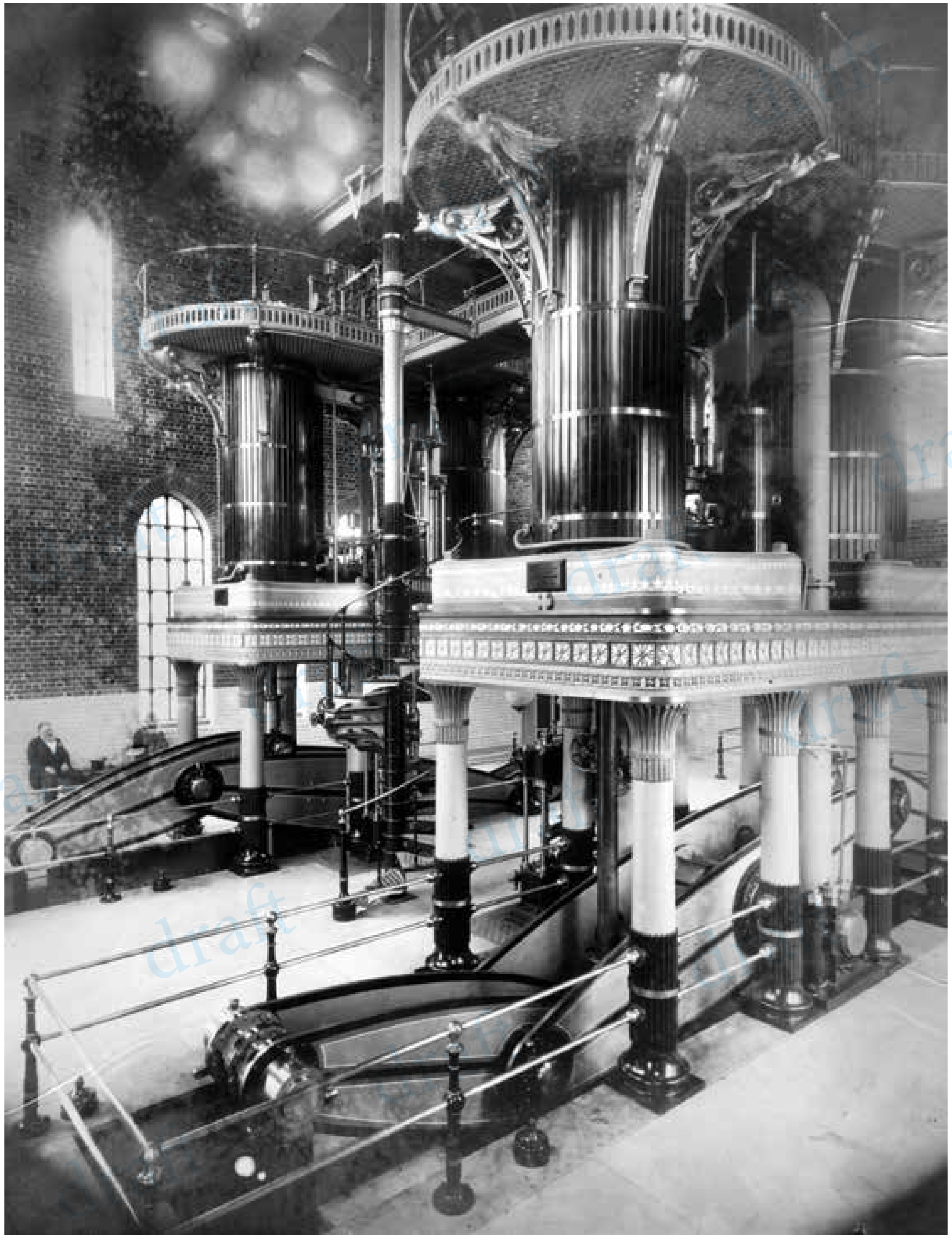

Fig. 2 Pumping engines at Whitacre, erected 1883

enjoy that level of service. Expansion of sources to the Rivers Bourne and Blythe, supplemented by smaller streams and wells, proved adequate until the late nineteenth century. The magnificent pumping station at Whitacre (Figs 2 and 3) housed two Boulton & Watt inverted compound beam engines on Egyptian-style decorative columns. The private water company was acquired by the Birmingham Corporation in 1876. But the system capacity of 20 million gallons per day left no margin for further growth or for improving sanitary systems.

James Mansergh, civil engineer, was consulted in 1890 to augment the water supply and recommended the Elan Valley in Wales, some 80 miles or so to the west, as the ideal source: it averaged 1,830 mm of rainfall each year; the shape of the valley would facilitate the building of dams; and the bedrock was impermeable so water would not drain away. Better still,

Fig. 3 Whitacre pumping station

Fig. 4 Craig Goch Dam © Craig Goff

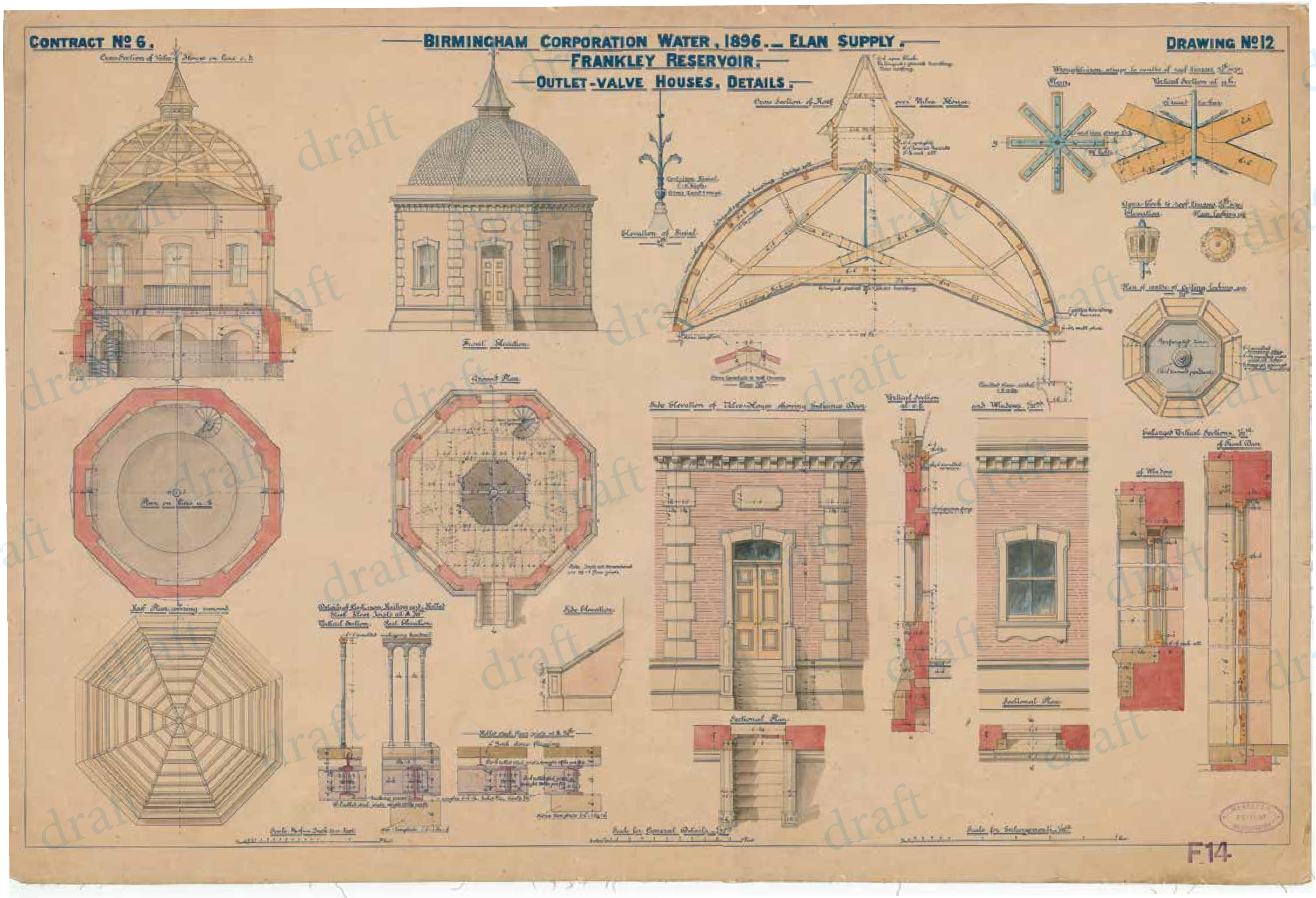

Fig. 15
Frankley reservoir outlet valve house details © Severn Trent Water