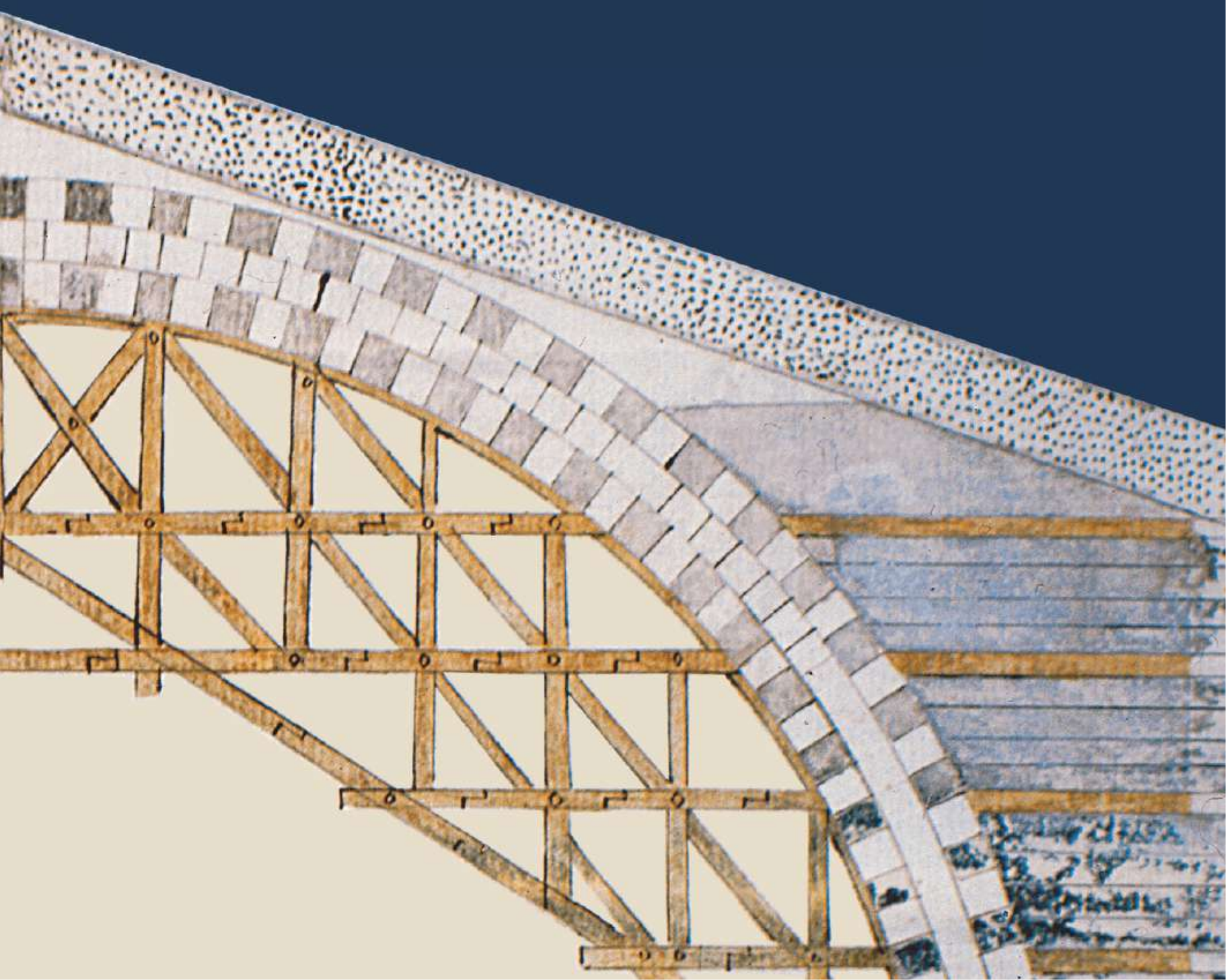
FOUR CENTURIES OF

XVI **SPANISH** XIX

ENGINEERING

OVERSEAS

MUSEO SAN AGUSTIN



FOUR CENTURIES OF SPANISH ENGINEERING OVERSEAS

Museo San Agustin, Manila

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It is indeed an honor and privilege to welcome this magnificent exhibition that celebrates the legacy and contribution of Spanish engineering in the overseas territories. With eight sections carefully approched, this exhibit guides us through a fascinating journey through four centuries and across four seas, exploring the influence and impact of Spanish engineering in shaping landscapes, infrastructures and societies overseas. From the construction of cities to the design of hydraulic systems, each section offers a unique window into how Spanish engineering not only transformed the physical environment, but also left an indelible mark on the culture, economy and development of these regions.

Upon going through this exhibit, it is impossible not to be in awe and admiration of the creativity, wisdom and technical prowess of those who defied the unknown and faced monumental challenges. I hope that this exhibition will serve as a source of inspiration and reflection, inviting all visitors to contemplate our shared past with a renewed sense of appreciation and respect for the diversity of cultural and technical contributions that have shaped our world.

On behalf of all those involved, I would like to express my sincere thanks to the Philippine and Spanish institutions that have loaned their pieces and to the teams that have worked to make this unique exhibition a reality. This aºdaptation of the exhibition that took place at the Archivo General de Indias and that now comes to the Philippines is the result of a collaborative effort that has brought together a collection of artifacts and historical documents that illustrate the laborious work of the engineers of the Hispanic monarchy in America and the Philippines.

May this exhibition be a lasting reminder of the importance of preserving and valuing our historical and cultural heritage, and may it inspire present and future generations to continue to explore, learn and collaborate in pursuit of a common future of understanding and cooperation.

MIGUEL UTRAY DELGADO
AMBASSADOR OF SPAIN TO THE PHILIPPINES

This year the Augustinian Order, under the Province of the Most Holy Name of Jesus of the Philippines, will celebrate the 420 th Anniversary of the completion of the building of San Agustin Church (1604-2024).

San Agustin is undoubtedly a primary and finest example of Spanish Engineering in the country. It is timely that the Embassy of Spain have chosen to inaugurate the exhibit "Four Centuries of Spanish Engineering Overseas (XVI-XIX)" here at Museo San Agustin. We are so deeply honored with this collaboration.

REV. FR. RICKY B. VILLAR, OSA
DIRECTOR
MUSEO SAN AGUSTIN

Once having reached the New World, the Spaniards embarked on exploring the coasts and interiors of regions from different centers of expansion that began in the Antilles, a headway that by the end of the 16th century had covered almost the entire American continent and had extended as far as the Philippine Islands, a bridge to Asia. In the midst of this progress, the "building of the territory" was taking place, in which European infrastructures merged with admirable pre-Hispanic precursors in the achievement of the services necessary for the explorer and conqueror to become a settler and inhabitant of the new lands. The greater part of the urban network of America had already been established by the end of the century, with the main cities following a characteristic regular pattern, the grid, while the city had become the fundamental focal point for the establishment of all kinds of relations, which over time led to the establishment of the most important infrastructures: hydraulic infrastructures for agricultural, urban and industrial supply (both mining and any other economic activity); maritime, land and river communications; systems for the protection of coasts against the brunt of nature and others for the defense of ports and cities from pirate attacks...all of which ultimately constitutes the basis of organizing the territory to make life easier in the new provinces.

In these processes, which were developed over more than three centuries in the continental territories of America and four on the Philippine Islands and Greater Antilles, military engineers, originally without affiliation to any organized group or system (16th - 17th centuries), then within the Corps of Engineers (18th - 19th centuries), performed army duties in the service of the Administration, mainly in defense works and in industrial facilities linked to it. Nevertheless, mainly from the 18th century onwards, they also participated in numerous important public works as technicians of the Crown. Civil engineers later joined their extensive labor (1799 - 19th century).

This exhibit is an adaptation of the exposition "Cuatro siglos de ingeniería española en Ultramar. Siglos XVI-XIX", which was held at the Archivo General de Indias in Seville in 2018, now enriched with new pieces related to the Philippine archipelago. Its objectives remain the same: to display in a cross-sector manner all or most of the branches of engineering and their development in America and the Philippines from the 16th to the 19th century; to highlight the importance of engineers in the service of the Spanish Crown in organizing the territory by adapting European techniques to the new environment and to the pre-Hispanic background; and to underline the existence of an immense documentary and cartographic heritage produced by the engineers and kept in the archives, a basic source for the study of the history of this group in Spain and overseas.

MARÍA ANTONIA COLOMAR ALBAJAR
Curator, former Deputy Director of the Archivo General de Indias

IGNACIO SÁNCHEZ DE MORA Y ANDRÉS
Curator, President of the Association of Spanish Knowledge-based and Engineering Companies (CÍES)

ACKNOWLEDGMENTS

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Alfredo Roca Pérez

INTRODUCTION

Engineering consists of applying knowledge to make possible: supplying water to people, farming fields, organizing the territory, uniting and defending it, improving industrial processes, transforming raw materials, transporting goods and merchandise, preventing natural disasters, harmonizing the growth of cities with the environment, and innovating.

These are essential and definitive activities for human development and economic progress; activities that engineers have been practicing discreetly and anonymously for centuries.

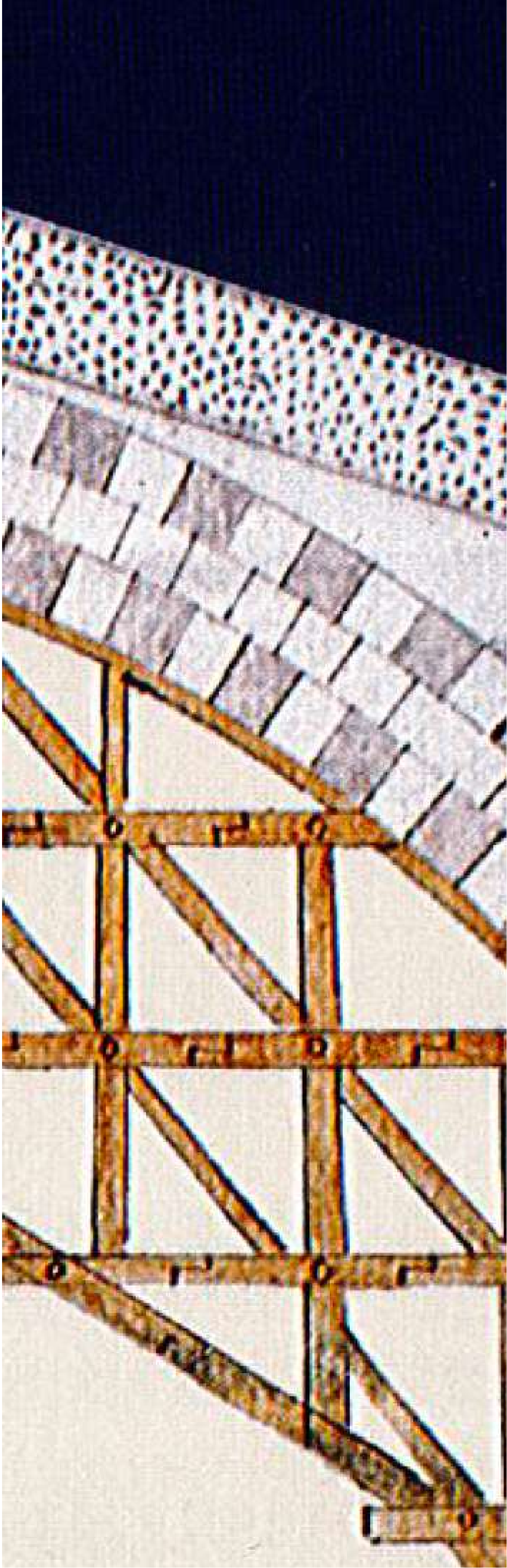
This exhibition, a continuation of the one held at the General Archive of the Indies on the occasion of the tricentennial of the first engineering ordinances promulgated in Spain in 1718, aims to recognize the work of those individuals who used their knowledge to improve the quality of life for others, designing infrastructure and machines that transformed the society of their time, envisioning the future.

The projects, reports, and work carried out by engineers in the service of the Spanish Crown in Overseas Provinces, which the participating institutions here carefully preserved, constitute one of the greatest technological heritages in the history of humanity, as very few nations in the world influences the history of a continent and archipelago. Therefore, an enormous work is presented in terms of territory: America and the Philippines, from the 16th to 19th centuries.

We greatly appreciate the hospitality of the Augustinian Fathers in hosting the exhibition in this magnificent cloister of the 16th-century San Agustín Convent, a UNESCO World Heritage site. Within these walls, visitors will explore eight areas with the purpose of providing a comprehensive view of the history of engineers and the various branches that existed during the study period. Starting with their military and civil legacy, we will journey through urban planning and territorial organization, hydraulic works, communications, mining, industry, ports, and fortifications, culminating in naval engineering.

The commendable contribution of religious orders to numerous public works over the centuries, particularly in hydraulic engineering, must be acknowledged. Augustinian friars such as Fray Diego de Chávez y Alvarado stand out in the sanitation of the Yuririapúndaro lagoon in Mexico. They also played a significant role in public buildings like the Alcaicería de San Fernando in Manila, designed by the Augustinian friar Fray Lucas de Jesús María for the accommodation of Sangleyes arriving from China for the annual trade.

We hope that this journey will attract the youth to study engineering, adults to consider and respect it for its value as a fundamental pillar of social well-being, and inspires researchers to explore new avenues of study in the fascinating and rich history that the Philippines and Spain share.



1. THE LEGACY OF ENGINEERS IN AMERICA AND THE PHILIPPINES

The organization of the Spanish Empire was forged in the 16th century. By the end of the century, most of the urban network in the Spanish overseas provinces had already been established, with the city becoming a fundamental element in a complex web of administrative, political, economic, cultural, defensive, and other relationships. This led to the implementation of hydraulic infrastructure for agricultural, urban, and industrial supply, land, river, and naval communication systems, as well as coast protection and defense systems for ports and cities. All of this ultimately forms the basis for the planning and construction of the territory.

In these processes, military engineers served the administration in military tasks, primarily in fortification works and in industrial installations linked to the army. However, they also devoted themselves to civil works as technicians of the Crown: in the 16th and 17th centuries as military personnel without affiliation to any organic entity; in the 18th and 19th centuries, within the Corps of Military Engineers founded in 1711 and, from 1799 onwards, also as civilian engineers, effectively supporting the monarchy's development policy with participation in public works and civil infrastructure and construction projects.

Cristóbal de Rojas (1555 - 1614)

Próspero de Verboom (1665 - 1744)

Military Engineers of the Crown, the Pioneers. 16th-17th Centuries

During the 16th and 17th centuries, under the rule of the Habsburgs, military engineers of the State were tasked with the defense of the empire. Overseas, due to piracy, their primary focus was on fortifying cities and ports that served as repositories for the gold and silver from the viceroyalties of Mexico and Peru. These locations served as terminals for the Fleet of New Spain and the Galleons of Tierra Firme, respectively. Foreign engineers in the service of the Spanish Crown, along with local engineers, executed the strategic defense plan for the Caribbean, Gulf of Mexico, and ports in the Pacific.

To address the shortage of Spanish engineering officers in their armies, Philip II facilitated the establishment of the Academy of Mathematics and Military Architecture in Madrid in 1582, founded by Tiburcio Spannocchi, where Cristóbal de Rojas taught. However, despite their limited numbers in America, military engineers occasionally collaborated on civil projects alongside architects, construction foreman, non-engineer military personnel, mathematicians, or cosmographers with scientific training and knowledge.

The Corps of Military Engineers. 18th-19th Centuries

The enlightened policy of the Bourbon dynasty shall oversee at the defense and security of overseas possessions and the promotion and exploitation of economic resources. During this period, military engineers become key pillars of defense and reforms, especially after being unified as a corps in 1711 by the engineer José Próspero de Verboom. The Ordinances of 1718 not only granted them their military duties but also many of the civilian duties of the era, including territorial recognition and intervention, particularly through structural public works.

Other subsequent ordinances and regulations (1768, 1774, 1791, 1803) define the evolution of the Corps, its division into three branches (1774), its reunification with General of Engineers José de Urrutia y de las Casas (1791), or its relationship with the Artillery branch. They also supervise the training of engineers in the Mathematics Academies of Barcelona (1720), Oran (1732), and Ceuta (1742); the examination-based entry system, requiring the acquisition of necessary knowledge; promotion based on merits in a hierarchy with the following ranks: general engineer, director engineer, chief engineer, second engineer, ordinary engineer, extraordinary engineer, delineator, assistant, and, outside the organization, voluntary engineer. They also deal with the development of their cartography and even matters such as their uniform.

Agustín de Betancourt y Molina(1758 - 1824).

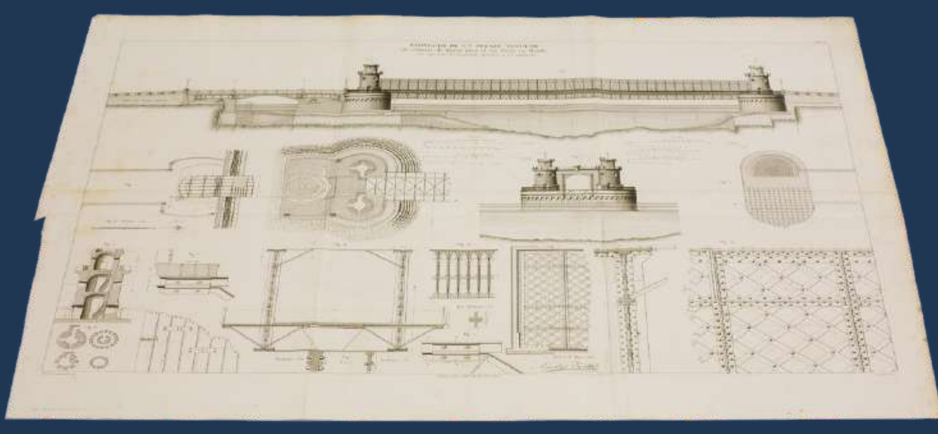
José de Urrutia y de las Casas (1739 - 1803)

Civil Engineers, Technical Developments, 19th Century

Civil engineering emerges as a branch of military engineering, as the latter cannot fulfill all its commitments in public works. The formal birth of Spanish civil engineering takes place in 1799 with the creation of the Corps of Engineers of the General Inspection of Roads, which complements and expans the mandate of the General Directorate of Roads established in 1785.

In 1802, Agustín de Betancourt y Molina founds the School of Engineers of Roads and Canals in Madrid, following the example of L'École Nationale des Ponts et Chaussées in Paris. In 1836, the Regulations of the Corps of Road Engineers are published, including those of the School, regulating its operation, duration of studies and the strict discipline to which students have to adhere. Throughout the rest of the century, there is a proliferation in its various branches.

Due to its late creation, the scope of action of civil engineers in territories overseas is limited to the islands of Cuba, Puerto Rico, and the Philippines, once the continental territories gained independence. However, military engineers initially prevail in public works, despite the Ordinance of 1803 limiting their functions to military tasks.



Manual of the engineer. Summary of most of the elementary knowledge and of application in the professions of the engineer and architect. Atlas of 103 sheets. J. Dumaine. Paris 1859, V. 2 Nicolás Valdés y Fernández, lieutenant colonel of engineers (1819 - alive in 1867). Daniel C. Zuellig Collection, Manila, Philippines.

2.CITY AND TERRITORY

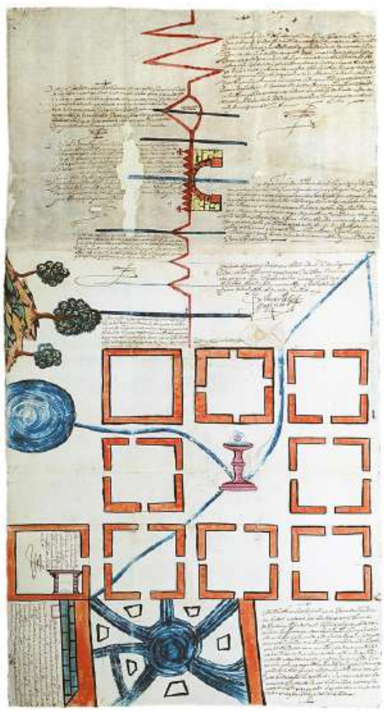
In the process of the Spanish colonization of the overseas provinces, resulted by successive laws for their administration, the conqueror transforms into a pacifier and settler. They become attached to the land and establish cities, a deed reflected in the "Act of Foundation," which, with the layout of the new population, becomes the symbol of settlement and colonization of the territory in the new lands.

From the beginning, cities are the nerve centers of all administrative divisions and the seats of civil and ecclesiastical bodies. Their role is to organize the territory according to their urban functions, serving as a supply base and commercial exchange factor, a bridgehead for deeper penetrations, a link in a broad chain of foundations, an element of control and consolidation of the indigenous population, ultimately a focal point of land ownership dominance (The City, 1989). The materialization of these attributes is reflected in the forms of spatial organization and relationships with the surrounding territory, planning the main infrastructures, which are the object of engineering.

The City in the process of Territorial Construction, 16th-17th Centuries

The main overseas populations were planned according to a geometric model, using a ruler and string. However, in almost contemporary evolution, irregular cities coexist, especially spontaneous growth mining towns, semi-conventional, and conventional cities. In the most important populations, this latter model prevails, with rectangular or mainly square blocks, the "Classic Model of the Hispanic-American City" in a grid that seems to begin with the second foundation of Guatemala and consolidates in the city of Lima. Whether in the center or not, the main square constitutes the core of city life where military, civil, religious, or mercantile activities take place, and it is where the main civil and religious buildings are located.

This city structure can already be glimpsed in the order decreed made by Emperor Charles V in 1523, although it is modified in the Ordinances issued by Philip II in 1573 when the urban network is already established. The typology of populations can also be established based on other parameters such as their location (maritime like Havana or Manila, inland like Mexico) or their predominant activity (commercial, mining, etc.). There are also mixed race cities (Mexico, Cuzco, and Quito), Indian towns, or towns with indigenous people converted to Christianity in whose layout a greater development of religious spaces is evident. These typologies determine the predominant infrastructures in each case.



Design of the new city of Veracruz, projected on the site of the Ventas de Buitrón, and on the road from there to Mexico.28 February 1590.Pedro Ochoa de Leguizamo, engineer (2ndhalf of the 16thcentury - beginning of the 17thcentury?).Facsimile reproduction.

Enlightenment and the City, 18th Century

As a result of Enlightenment policies brought along by the Bourbon dynasty, a new urban thrust impulse emerges, driven by colonial growth and demographic increase. Starting with the first Administrative Ordinances issued for Cuba in 1764, reflecting those of 1718 and 1749 for Spain, administrators progressively shall assume various urban functions, as well as the renewal of the cartography that is evident in the hydrographic chart of the Jesuit Pedro Murillo Velarde:

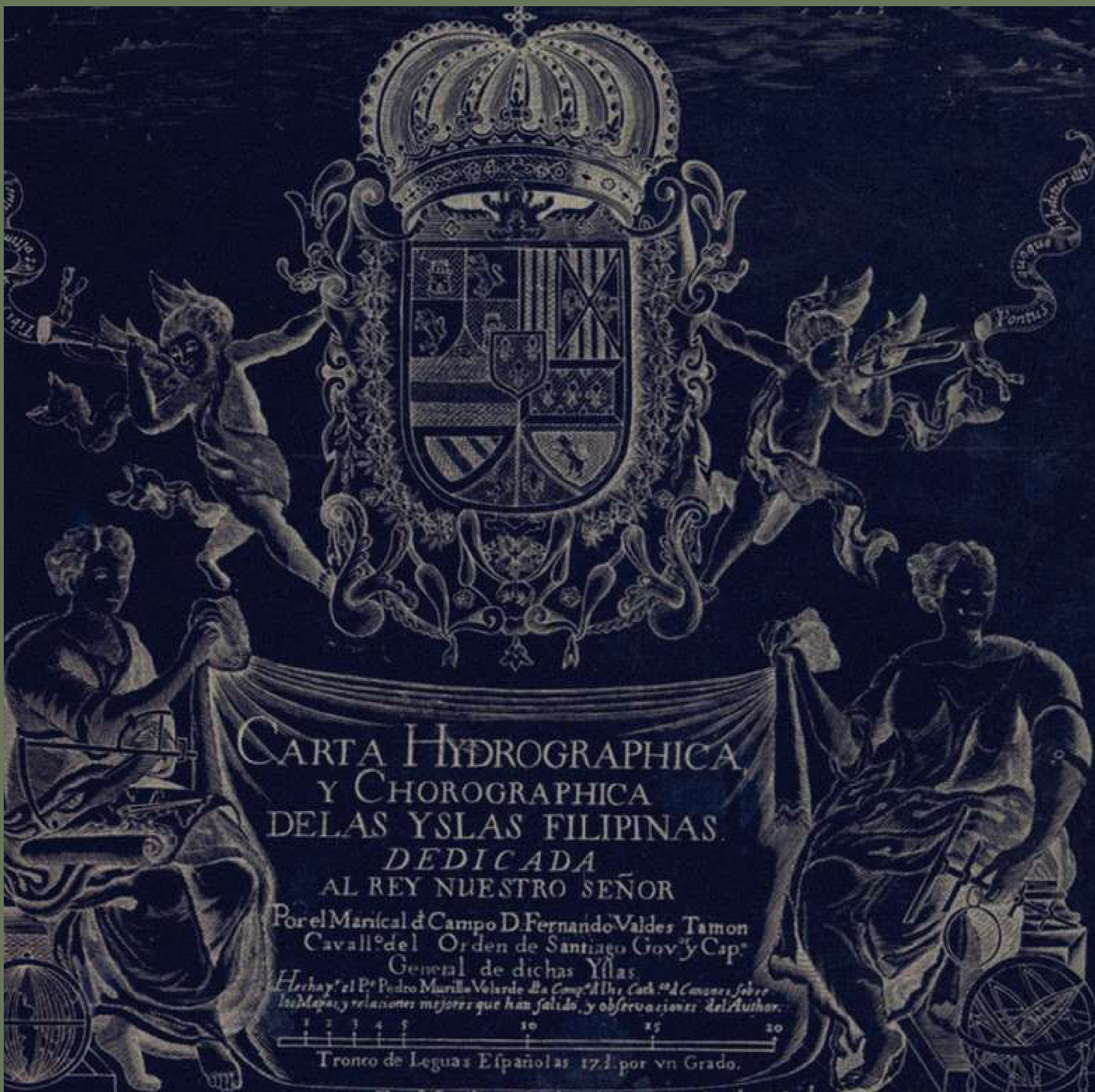
- Modernization of Cities: Implementation of water supply infrastructures, communication networks, sanitation systems, street lighting, disaster prevention, etc.

- Beautification of the Urban Landscape: Construction of important buildings, embellishment of streets and squares with monuments and fountains, creation of green spaces such as parks, promenades, and botanical gardens, and improvement of poorly-designed public spaces.

- Effective Organization of Cities: Division into "quarters" and neighborhoods with their own "Ordinances," regulations for the cleanliness of streets and facades, and the establishment of good order and organization within the cities.

- New institutional aim: Reinforcement and defense of borders, expansion of provincial boundaries through colonization or repopulation of marginal areas, and the rebuilding of destroyed cities like Guatemala and Concepción de Chile.

Graphic composition based on the "Hydrogrphic and Chorographic chart from the Philippines".

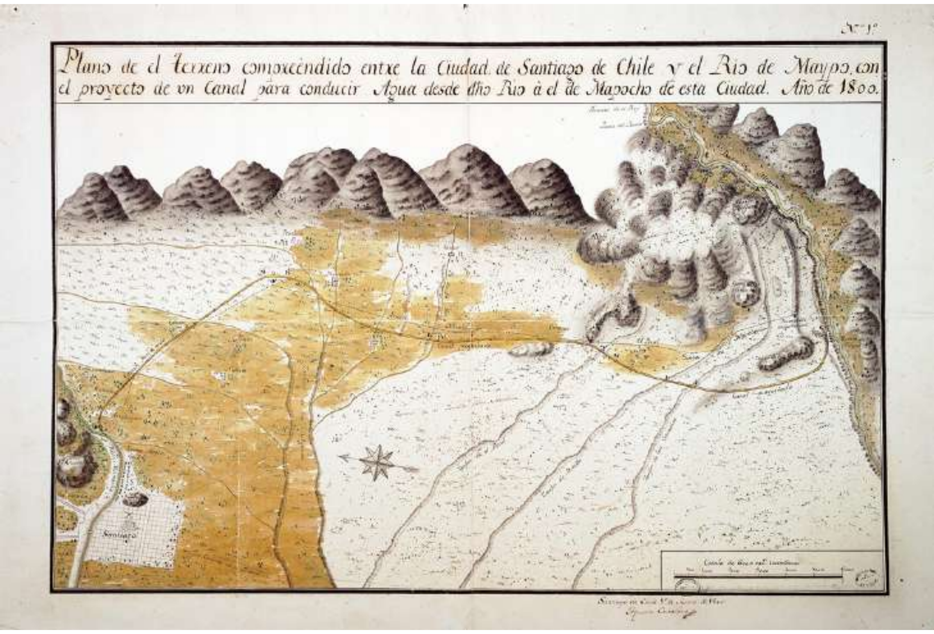


Graphic composition based on the "Hydrographic and Chorographic chart from the Philippines".

3. HYDRAULIC WORKS

The Spanish brought significant knowledge of hydraulic infrastructure to America, but in many cases, they had to adapt them to the environment and those of the established cultures, which were highly developed in some aspects, causing admiration among the Spanish forces. The technical expertise of the Aztecs stands out in techniques implemented for water supply, agricultural production in chinampas, and for sanitation and protection against disasters (Tenochtitlan). Similarly, the Incas demonstrated advanced techniques in their cultivation on ridges or platforms and in terracing.

There was a mixed engineering approach that involved the application of European instruments, especially in the construction of aqueducts, using water wheels and weirs. However, indigenous techniques were also employed in other works such as supply channels. Elements of hydraulic engineering were also applied to industrial engineering, including mining operations.



Land between the city of Santiago de Chile and the Maipo River,with the project of the Maipo or San Carlos Canal from said river to the Mapocho River, in this city. Santiago de Chile, 1 August 1800.Agustín Caballero, engineer (fl. 1796 - 1800).
Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Perú y Chile, 141.

Urban irrigation, the productive landscape

During the colonial period, European techniques were employed to irrigate fields situated at higher levels than the flowing water. These included "azudes" or water wheels (ñoras in Murcia), and norias, which served both for irrigation and industrial purposes. In the Americas, a more advanced system of the noria, known as the "malacate", was used. It operated without gears and experienced fewer breakages. Finally, the "cigoñal" (shadoof) was used for domestic water supply and small gardens.

In Mexico, after capturing water, it was directed to a large reservoir or "jagüey". From there, the main distribution canal or apantle madre, along with secondary canals, formed an organized supply network. Pre-Hispanic canals and aqueducts were also still in use.

In the Peruvian Viceroyalty, large irrigation engineering works were generally not constructed. The Spanish often reused the Inca network of channels, with the Canal de Maipo or de San Carlos in Santiago de Chile (1743-1809) being an exception. This canal diverted waters from the Maipo River to the Mapocho River, serving both irrigation and urban water supply. The project, completed by engineer Agustín Caballero, was a significant achievement.

In Trujillo, Peru, the irrigation canal known as "La Mochica" (16th-17th centuries), which derived its waters from the Moche River, dedicated one of its branches to irrigation.

Urban water supply, the essential provision

Major public works for urban water supply in the Americas were undertaken in the 16th century when the classical idea of water as a common good resurged with the Renaissance.

The water source could be a spring or a river, and the water's journey followed stages of catch basin, aqueducts, conduits, and water fountains or outlets.

For river catch basins, dams (different from irrigation wheels) and reservoirs were required. Examples include the Olla and Los Santos dams in Guanajuato, and the San Ildefonso dam in Potosí.

Notable aqueducts include the Zanja Real of Havana (16th-19th centuries), the Veracruz aqueduct (18th-19th centuries) in Mexico, and the two alternative aqueducts, the Pínula and Mixco, which served Nueva Guatemala (18th century).

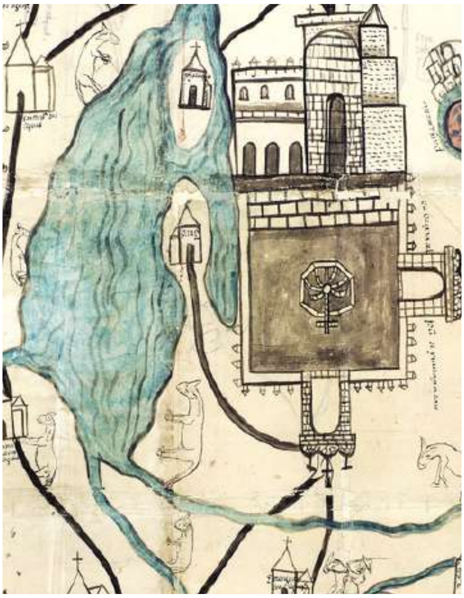
The stone aqueducts of New Spain deserve special mention, which have amazed travelers: Chapultepec, Santa Fe, and Belén in Mexico City, Cempoala (16th century) by Father Francisco Tembleque, and Querétaro (Sitio - Xalpa, Cuautitlan) and Morelia, among others (18th century).

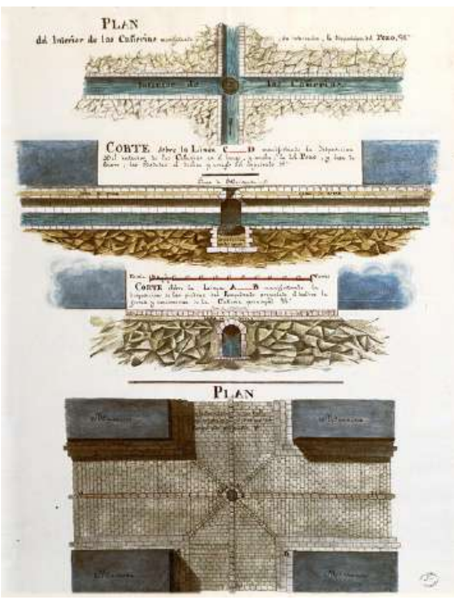
In South America, notable examples include the aforementioned Mochica aqueduct serving Trujillo in Peru, the San Carlos aqueduct for Santiago de Chile, and the Potosí aqueduct in Bolivia.

In the Philippines, in the 19th century, water supply for the city of Manila was implemented by Chief Engineer Genaro Palacios Guerra in the Public Works Department.

City of Trujillo and the Chimú valley in Perú and the water pipes in the territotry.1760.Miguel Feijóo de Sosa, councilman of Trujillo (1718 - 1791).Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Perú y Chile, 39.

Town of Yuririapúndaro and others dependent on it, with the great lagoon sanitized by fray Diego de Chávez y Alvarado (OSA) through the canalization of the Lerma River.1580.Cristobal de Vargas Valadés [attribution]Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - México, 24.





Plan and sections of the paving and sewers of Havana.10 de julio de 1824. Arsène Lacarrière-Latour, french arquitect (1778 - 1837). Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Santo Domingo, 745.

Sanitation, key to public health

Sanitation comprises the set of works, techniques, and devices aimed at establishing, improving, or maintaining appropriate sanitary conditions. From the perspective of civil engineering, efforts in overseas were focused on combating diseases and epidemics, which were causes of demographic catastrophes, through direct measures supported by the legislation of the Administrative Ordinances:

- Establishment of cemeteries away from the core of populations.

- Street paving. During the Enlightenment period, major colonial cities undertook paving and cobbling works: La Guaira in Venezuela, Lima, or Havana, the latter using granite cobblestones from Boston.

- Cleaning services outlined in administrative and city ordinances.

- Sanitation of marshlands through drainage with ditches or drainage channels or wells. Also, facilitating the continuous circulation of water, as in the case of the town of Yuririapúndaro.

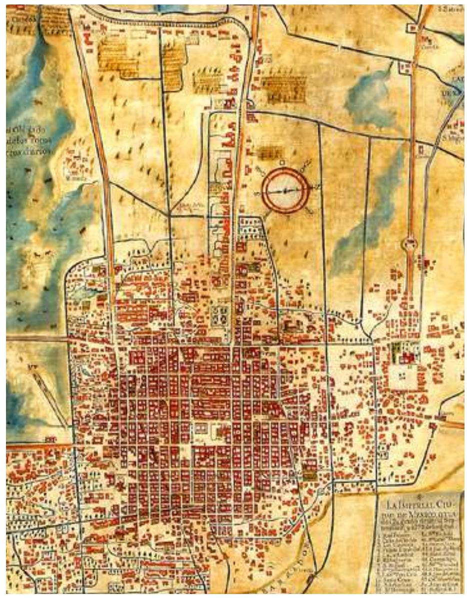
- Establishment of sewerage systems, a very late phenomenon, with the exception of the city of Santo Domingo, equipped with them since the 16th century.

Floods, the indomitable force of water

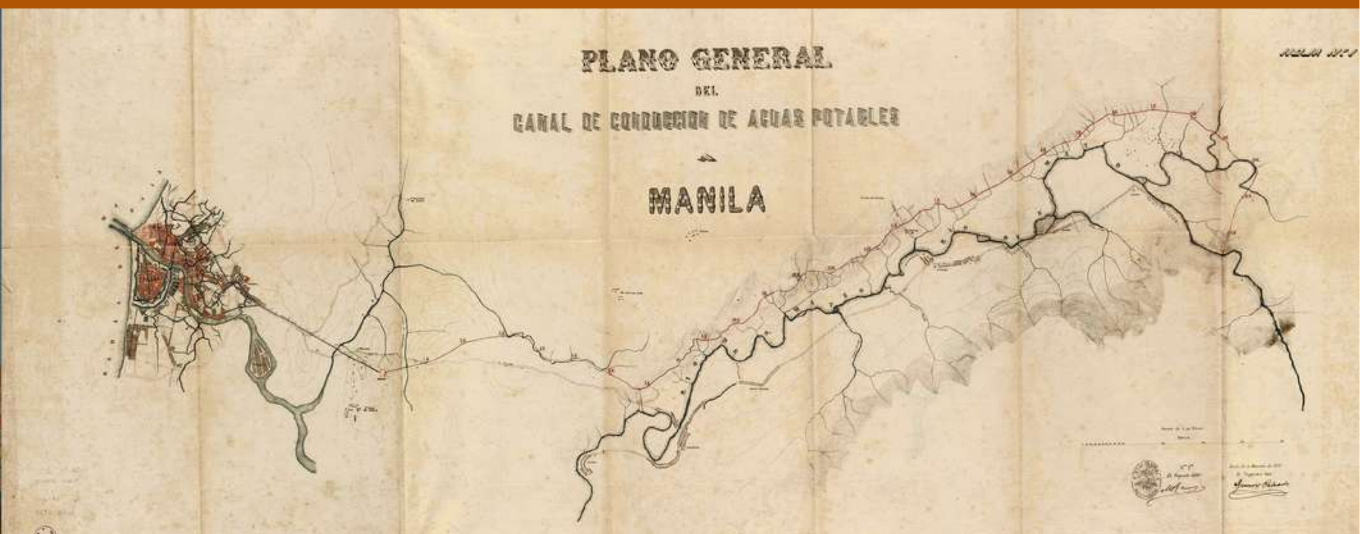
Overflow and floods were prevented with levees or channeling walls and channel cleanings, as well as drainage works, such as the one for the Mexico City Lake.

This colossal hydraulic engineering project, the most important of the colonial period, took place between the 16th and 19th centuries. It involved draining the lake basin where the city of Mexico-Tenochtitlan was located, subject to severe and recurrent floodings due to the silting of the surrounding lakes (Zumpango, Xaltocán, San Cristóbal Ecatepec, and Texcoco).

The project of partial drainage of the basin, initiated by Enrico Martínez in 1608, diverted the waters of the Zumpango lagoon, near Huehuetoca, towards the Atlantic through a tunnel and then an open channel. After multiple setbacks, including tunnel collapses and new floods, the drainage of the first three aforementioned lagoons was completed in the late 18th century, with the drainage of the Texcoco lagoon and the city's sewerage system still pending. A comprehensive drainage project was proposed in 1773 but was not resumed until 1856, already in the era of independence.



Mexico City project with ditches, rivers, slopes and drainages to prevent floods. 1753. Domingo de Trespalacios y Escandón (1706 – 1777). Facsimile reproduction. Royal Academy of History, Madrid, Spain. Canvas - 36, No 285.



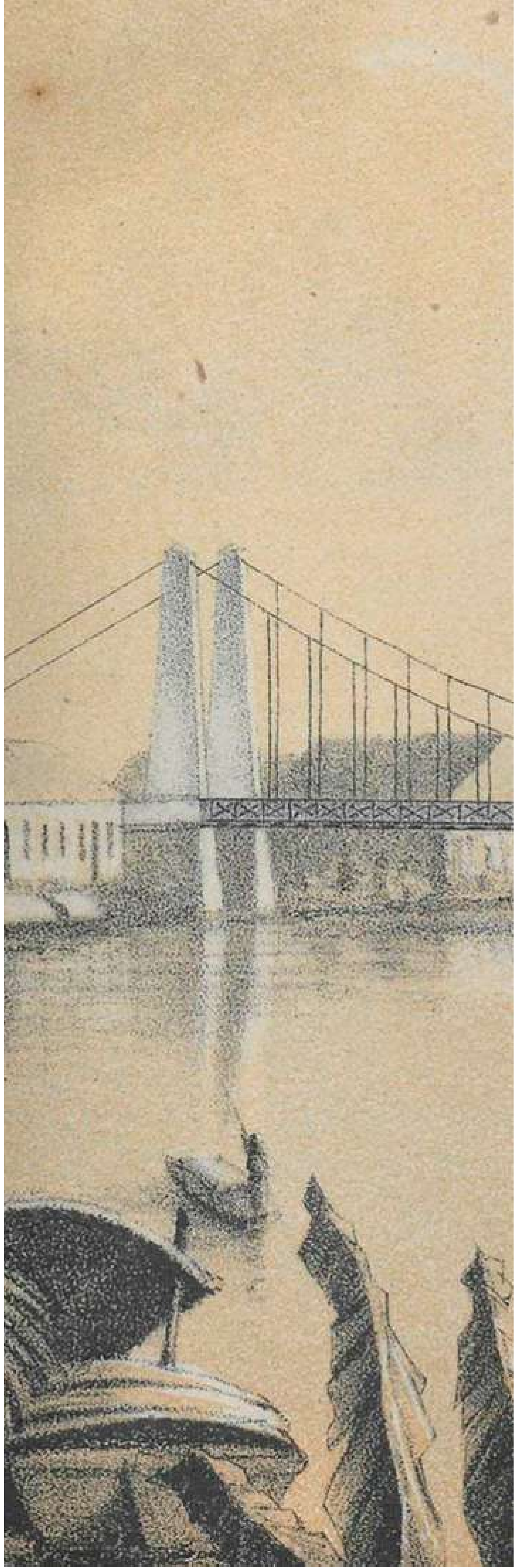
Plan of Manila and its suburbs with the layout of the water conduit.11 November 1869. Genaro Palacios, chief engineer second class, later first class, director of works in the service of the City Council of Manila (1839 - ?). Facsimile reproduction.National Historical Archive, Madrid, Spain. Ultramar, MPD. 4537.

4. COMMUNICATIONS: ROADS, BRIDGES, NAVIGATION CHANNELS

Despite the admiration of the Spaniards for the Aztec causeways of Tenochtitlan, Mexico, and the extensive road network of the Incas, most colonial roads were mule or horse trails, traversed on foot, by pack animals, or by tamemes or porters. Vehicular roads were less common, sometimes occupying partial sections of a route. The most important colonial roads were associated with the transport of silver and the fleets of the Carrera de Indias.

The main challenges of the roads were encountered at river crossings, which were often swift-flowing, with unexpected floods and irregular flow patterns. The typology of bridges adapted to the hydrography, orography, topography, and climatology of the territory, combining pre-Hispanic and European techniques in bridges made of wooden beams, and stone and lime.

Navigation on rivers and lakes was common in Spanish America as it offered a less costly and more efficient alternative to challenging overland transportation. Hence, there were projects to open navigation and transportation channels in Colombia (Canal del Dique), Cuba (Canal de Güines), and across the isthmus of the continent (Tehuantepec, Nicaragua, and Panama).



Detail of the itinerary sketch of the road from Las Piñas to Calamba, a layout that appears to coincide with the current Asian Highway 26, an important transportation axis on the island 1897. Carlos de las Heras y Crespo, commander of engineers (1860 - 1926).

Roads, Arteries of the Territory

The main roads were linked with trade and economic routes:

New Spain

The Camino de Tierra Adentro (Mexico-Santa Fe) and the Camino de los Virreyes (Mexico-Veracruz) were important routes for transporting the silver from Zacatecas, Guanajuato, and other mines, which was sent to the metropolis in the Flota de Nueva España from the port of Veracruz. The Asian Road or the Chinese Road (Mexico-Acapulco) connected the Philippines through the Nao de Acapulco or the Manila Galleon.

Panama

The transport of Potosí silver, which was then loaded onto the galleons of Tierra Firme, was carried out through the isthmus routes (Panama-Nombre de Dios and later Portobelo). In the 18th century, this route went into crisis as Potosí silver started to be shipped through Buenos Aires.

New Kingdom of Granada

The challenging geographical conditions determined that the main communications were carried out through the Magdalena River. In Ecuador, with difficult communication with neighboring provinces, the route from Quito to the sea was opened through the Esmeraldas River. In Venezuela, the export of cocoa was carried out through the mule train route road of La Guaira.

Bridges, land over water
The Bridges of Manila

Various techniques for crossing rivers coexisted, blending pre-Hispanic and European methods, sometimes resulting in mixed types:

- Ferries, cable cars, hanging baskets, or hanging bridges.
These are the simplest systems, consisting of ropes stretched between the two banks of a river or canal. Also included are barges, flatboats, or rafts used either temporarily or permanently.

- Floating bridges.
These bridges are placed over rivers with stable currents and flows, constructed from boats anchored at each of their ends with a wooden platform. A variation includes movable bridges allowing alternating river navigation. The bridge of boats over the Pasig River in Manila is noteworthy, used between the partial destruction of the Puente Grande (1863) and the construction of the Puente de España (1876).

- Suspension bridges.
Using liana ropes, and of Incan origin, these are called cord or hammock bridges. They were used over very fast and uneven currents, later evolving into technology that uses steel cables.

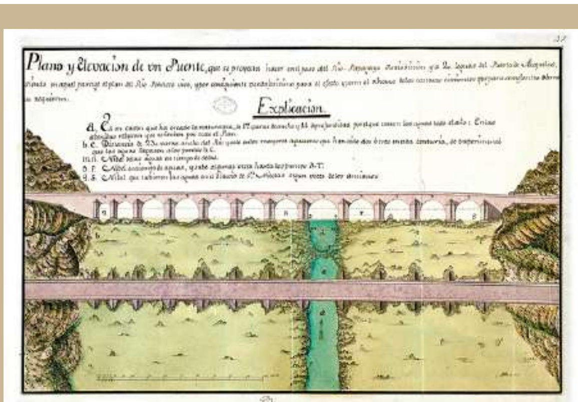
- Wooden bridges.
Utilized since pre-Hispanic times, these are log or beam bridges, commonly found in Peru. The simplest were grid bridges supported on pilings for soft and swampy terrain. In the Philippines, they were called "pantalanes."

- Stone bridges.
Primarily urban, the safest were lime and stone bridges constructed with keystone forming arches. They required formwork for construction.

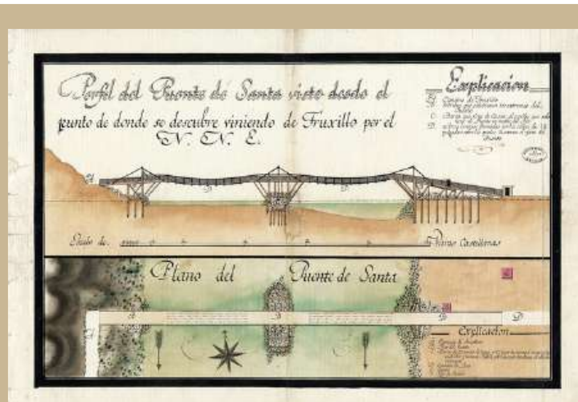
- Metal lattice bridges.
From the 19th century onward, these became the predominant type for railways.

- Straight-deck suspension bridges of European tradition.
Using steel cables or iron links (different from pre-Hispanic criznejas and colonial leather rope bridges).

- Bridges with lowered vaults.
Some of these types are illustrated in the album of Manila bridges, containing images from the last third of the 19th century.

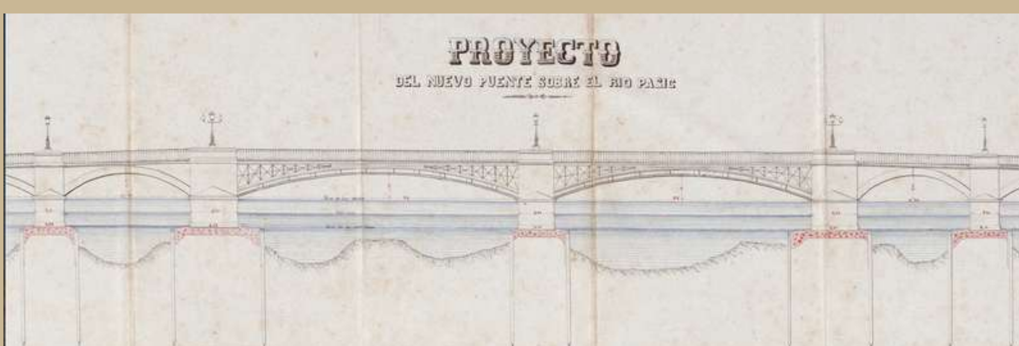


Plan and elevation of the bridge on the "Road to Asia", from Mexico to Acapulco.28 May 1784.Rafael Vasco, lieutenant colonel of the Asturias regiment.Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - México, 394.



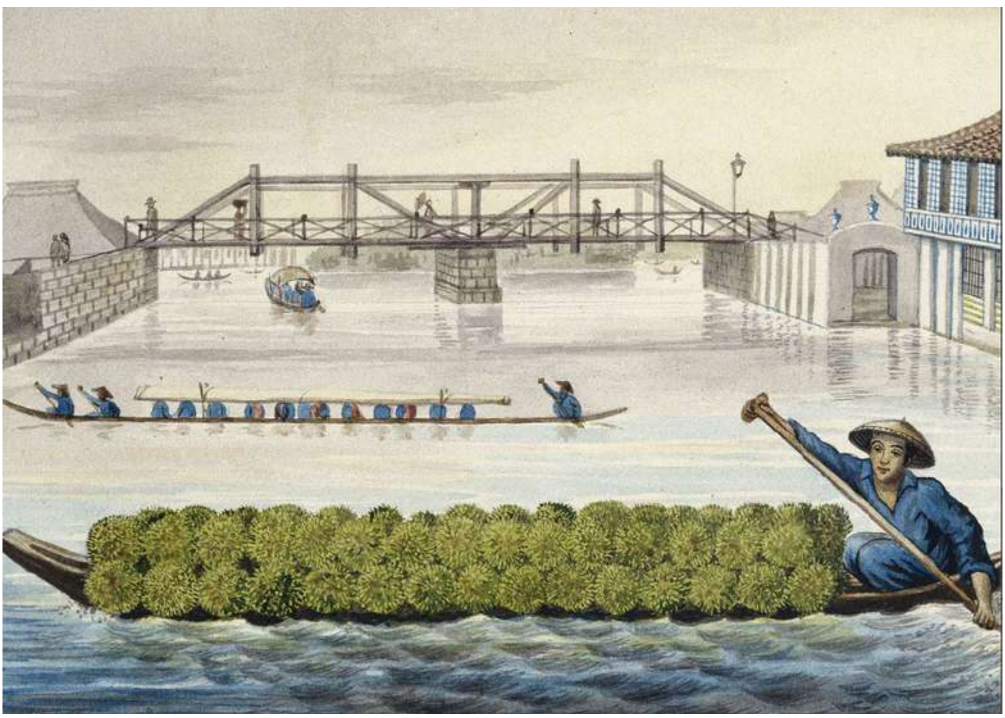
Profile and plan of the Santa Bridge: Reconstruction of the bridge projected by José Coquette Gallardo.28th January 1811. Antonio de Ugartevidea. Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Perú y Chile, 167.

Stone bridge of Manila built between 1626 and 1630 on the Pasig River, partially destroyed by the 1863 earthquake.1847.José Honorato Lozano, painter (1821 - 1885).Facsimile reproduction.National Library, Madrid, Spain. DIB/15/84/4.



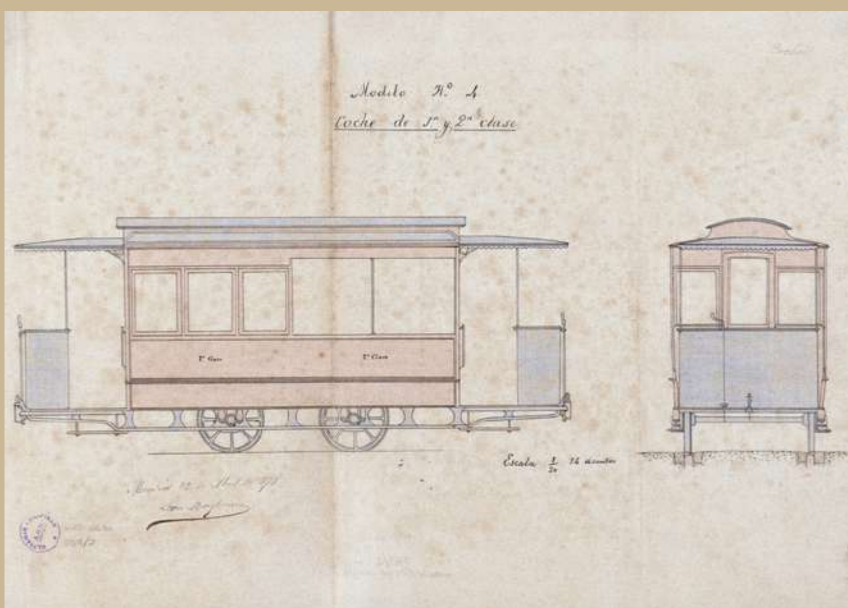
Design of the first- and second-class car of the Manila trams.Madrid, 22 April 1878.León Moussour.Facsimile reproduction.National Historical Archive, Madrid, Spain. Ultramar, MPD. 6464.

Manila Tramway Layout Plan created by León Moussour, consisting of five blood traction lines, one of them converting to steam traction in 1882.Madrid, 22 April 1878.León Moussour. Approved by Inspector General Manuel Ramírez Bazán.Facsimile reproduction.National Historical Archive, Madrid, Spain. Overseas, MPD. 6460.

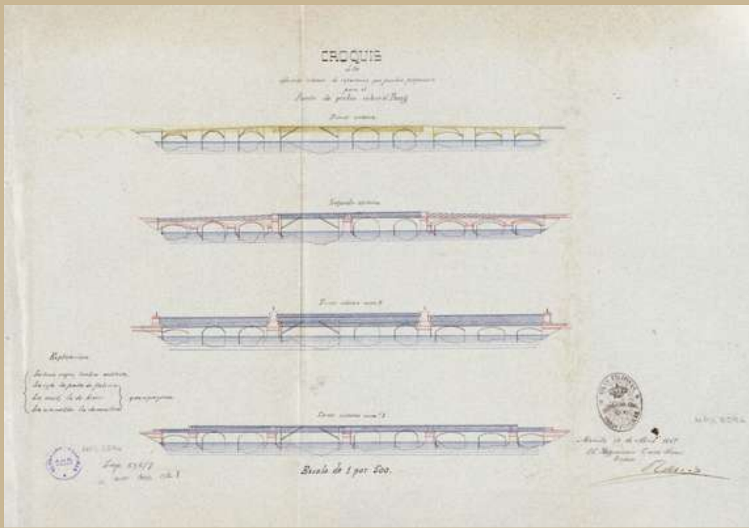


Two-span wooden lattice bridge called Quinta Bridge in San Miguel, outside the walls of Manila.1847.José Honorato Lozano, painter (1821 - 1885).Facsimile reproduction.National Library, Madrid, Spain. DIB/15/84/11.

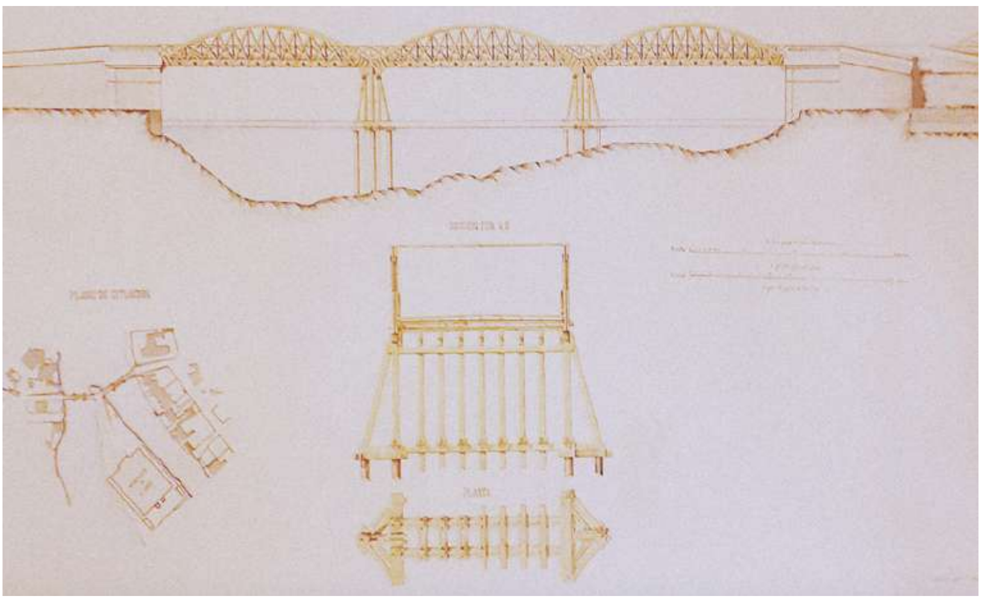
View of the Suspension Bridge, taken from the Escolta.15 May 1859Baltasar Giraudier, lithographer.Facsimile reproduction.National Library, Madrid, Spain. ER/2241 (8).



Design of the first- and second-class car of the Manila trams.Madrid, 22 April 1878.León Moussour.Facsimile reproduction.National Historical Archive, Madrid, Spain. Ultramar, MPD. 6464.



Proposed systems for the reconstruction of the stone bridge over the Pasig River, which collapsed in its central part in the earthquake of 1863. 12 April 1867.Casto Olano Irizar, civil engineer (1834 - 1909).Facsimile reproduction.National Historical Archive, Madrid, Spain. Ultramar, MPD. 5594.



Section of the Ayala wooden bridge, along with another section from the San Miguel district, converges on Convalescence Island. 1876.Eduardo López Navarro, civil engineer, director of the Port of Manila (1841-1919).Facsimile reproduction. University Library UPM _ ETSI Roads, Canals and Ports, Madrid, Spain.

Navigation Canals, Major Transport Routes

Unimplemented Projects:

- Güines and Batabanó Canal in Cuba.

Planned between Havana and Güines to boost the trade of wood, tobacco, and sugar. The project, proposed by Félix and Francisco Lemaur in 1796, was suspended when the first railway line of the Spanish administration was established in the area.

- Canal in the Isthmus of Tehuantepec.

Suggested in 1774 by engineer Agustín Crame in a report to Viceroy Antonio María de Bucareli.

- Nicaragua Interoceanic Canal.

A project considered as early as 1620 by the flemish Diego de Mercado, it was discarded in the 1781 leveling plan by engineer Manuel Galisteo due to technical difficulties in resolving the elevation difference between the Pacific Ocean and Lake Nicaragua.

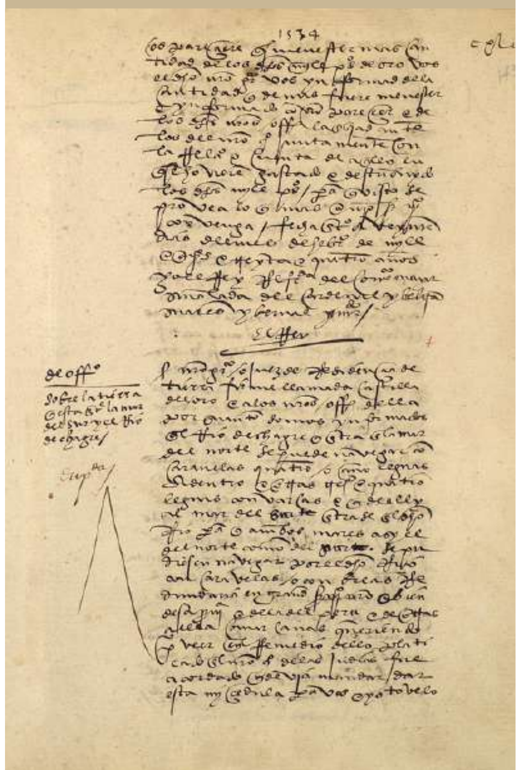
Completed projects:

- Panama Interoceanic Canal.

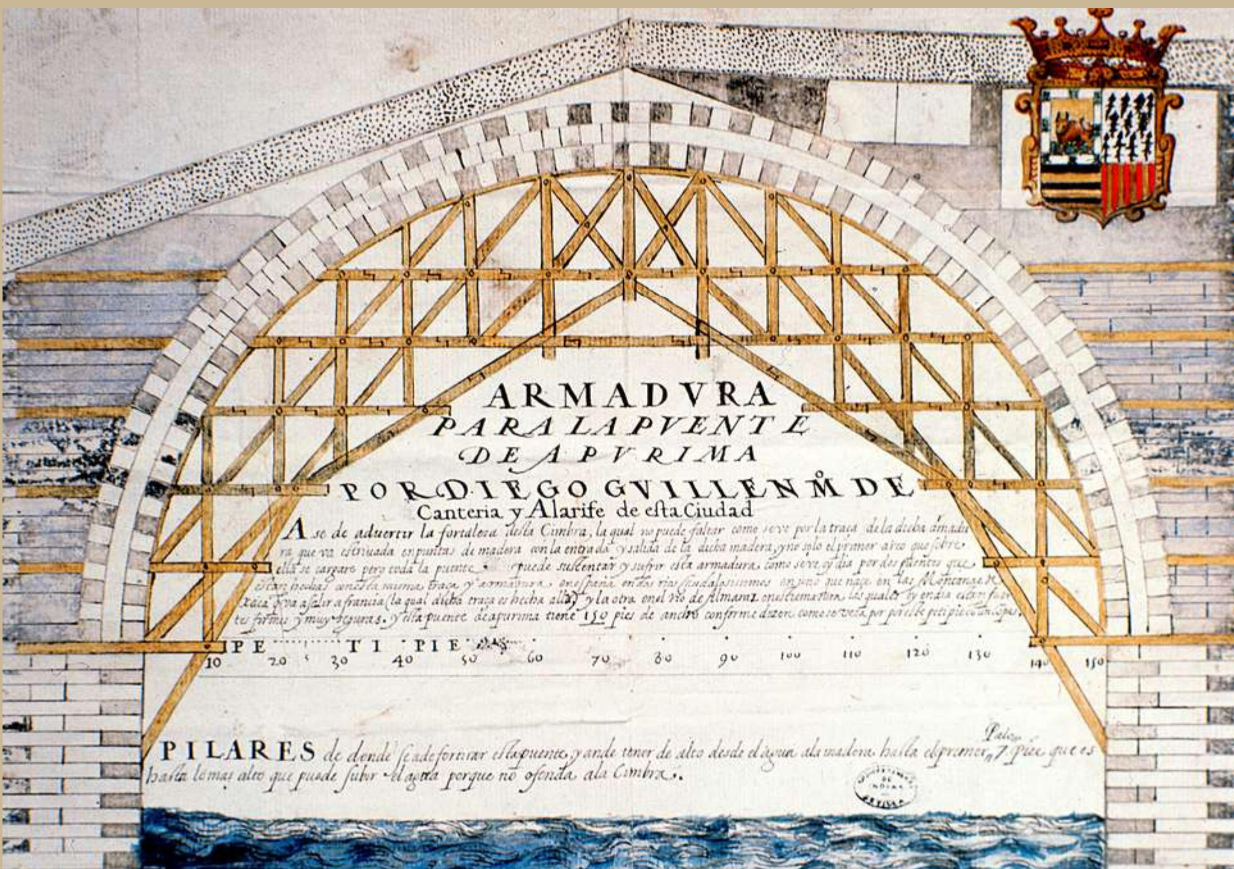
Originally proposed in the early 16th century according to imperial provisions by Emperor Charles in 1533-1534, the canal was not completed until the year 1914. This canal traversed the Panamanian isthmus through the Chagres River and the land strip between it and the Pacific Ocean.

- Dique Canal, Colombia.

The project for a canal between the city of Cartagena and the Magdalena River to facilitate communication with the interior of the territory became a reality in 1650, thanks to the efforts of engineer Juan de Somovilla y Tejada, with subsequent restoration work by other engineers.



Royal Decree of King Charles I to the governor or judge of residence and to the officials of Tierra Firme so that they may investigate with experts the land between the Chagres River and the South Sea and see how to establish a navigable canal between the two.Toledo, 20 February 1534.Facsimile reproduction.General Archive of the Indies, Seville, Spain. Panamá, 234, L.5, f.143 r-v.



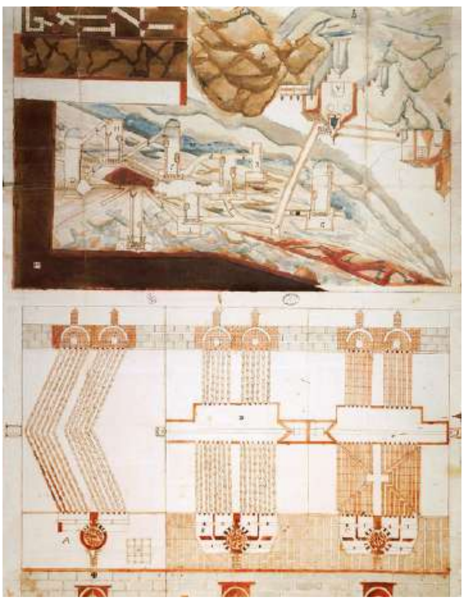
Armouring for the bridge of Apurimac.1619.Bernardo Florines, engineer and Diego Guillén, master mason.Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Perú y Chile, 203.

5.MINING ENGINEERING: THE LIFEBLOOD OF THE EMPIRE

One of the driving forces behind Spanish expansion into the American territories was the discovery of precious metal deposits, giving rise to myths such as El Dorado. By 1560, the main mining centers of the continent had been established. In terms of gold, these included Carabaya, Chuquibo, La Paz, Chayanta, and Zaruma in Ecuador. Regarding silver, notable mines were Taxco (1534), Zacatecas (1546), Guanajuato (1548-1558), Pachuca, and Real del Monte (1552) in New Spain. In addition, there were mines like Porco and especially Potosí (1545) in the Charcas province (Bolivia), and Castrovirreina (1555) in Peru.

Starting from 1555, thanks to the experimentation of Bartolomé de Medina from Seville, silver purification would be done through the amalgamation process, which required the use of mercury. For the production of silver in Potosí, mercury from the Peruvian mine in Huancavelica was employed. In New Spain, the mercury from Temascaltepec, Sierra de Pinos, and Chilapa couldn't meet the Mexican production needs, leading to regular shipments from Almadén (Ciudad Real) and occasional ones from Idrija (Slovenia).

Santiago del Real de Minas azogue oven of Nuestra Señora de la concepcion, in Nueva España, ready to remove the metal without reverb glasses or pots.Santiago 1648.Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Minas, 54.



Interior plan of a mine with its galleries and hand lathes and of the embankment where the Bustamante furnaces are located with their quicksilver pipes, possibly from Almadén. 1752.Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Minas, 57.

Mercury Extraction and Metallurgy

Mercury mining, much like silver mining, faced challenges in prospecting and operations, involving open-pit excavations, shafts, and inclined tunnels.

Material extraction to the surface was carried out using a contraption called "malacate." Mechanization for internal transport was difficult due to the irregular layout of tunnels and galleries. In Almadén, various types of carts of increasing capacities for transporting ore can still be found.

Regarding mine drainage, initially, manual winches were used in Almadén mines to collect water in animal skin bags. These winches were later replaced by pumps, and in 1805, a steam engine was introduced – the first in Spanish mining. It was under construction from 1787 and operational until 1878.

Mercury production had its own technique, which traveled back and forth between Spain and America. The "jabeca" furnaces used in Almadén in the mid-16th century were introduced in Huancavelica in 1596 and later replaced by reverberatory furnaces, which were highly polluting. To address their significant toxicity, in 1633, Lope de Saavedra Barba, known as "el Buscón," designed the so-called "horno busconil" or "aludel furnace," which was more profitable and pollution-free. In 1647, the mine steward of Huancavelica, Juan Alonso de Bustamante, introduced these furnaces to Almadén under the name "hornos Bustamante." The employed system came to be known as the "Almadén method."

Exploitation of Precious and other Metals

In general, during the colonial era, deficient techniques were employed in the prospecting and mining operations. In excavation, the vein was followed from its outcrop with open-pit workings or through inclined tunnels and shafts, creating large chambers without proper exploitation or safety plans.

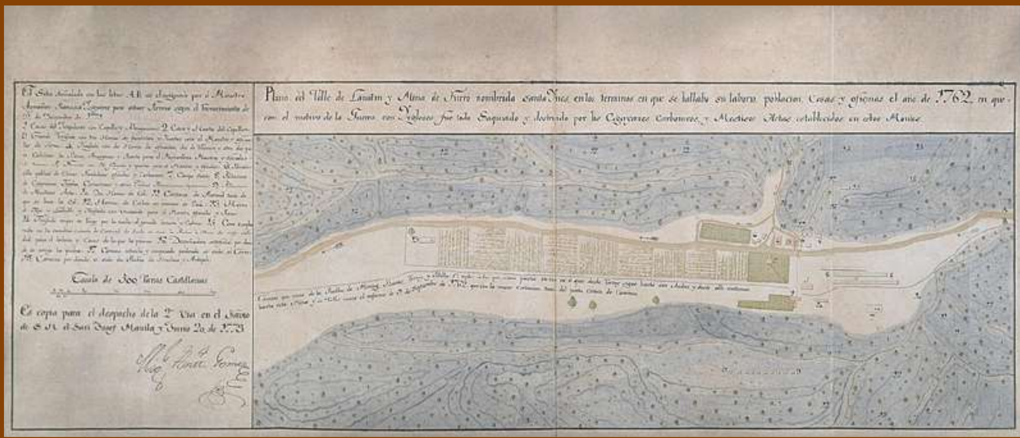
The irregular layout of tunnels and galleries prevented the mechanization of ore and water transport for a long time. These tasks were primarily carried out manually by workers, initially on their shoulders and later using wheelbarrows.

Water drainage in hills with high-altitude veins could be achieved through drainage galleries that emptied by gravity. Where this solution was impractical, various types of water drainage machines were used, which were adopted late in the overseas territories: stepped manual winches, operated by one or two men, were prevalent until the early 18th century; waterwheels powered by draft animals, as seen in San Juan de Rayas, Guanajuato; windlasses or winches, a significant advancement in Mexican mining in the 18th century; and finally, steam engines, which were also used for material extraction.

In silver metallurgy, initially, Castilian melting furnaces and reverberatory furnaces were used in Mexico, along with indigenous Peruvian "guairas." To process low-grade ores, the amalgamation system was widely adopted (Bartolomé de Medina, 1555), later perfected under the name "beneficio de patio," with mercury as a fundamental element for purification.

Map and general geographic table of the measurements of the mines named Mellado, Saucedo and Quebradilla, in the Real de Guanajuato, their mouths, posts and the workings it demarcates.1704.Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Minas, 102.

New method of working mines in Peru, proposal made by sergeant major Gaspar Sabugo, in the proceed of modernitation of the extraction and refining of metal and systematization of work in underground mineas at the end of the 17thcentury.1790.Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Perú y Chile, 121.



Plan of the Lanatin Valley and Iron Mine named Santa Inés, in the terms in which its labor, population, houses, and offices were in the year 1762 was plundered and destroyed. Manila, 1773. Miguel Antonio Gómez, engineer (1731 - f.s. XVIII).

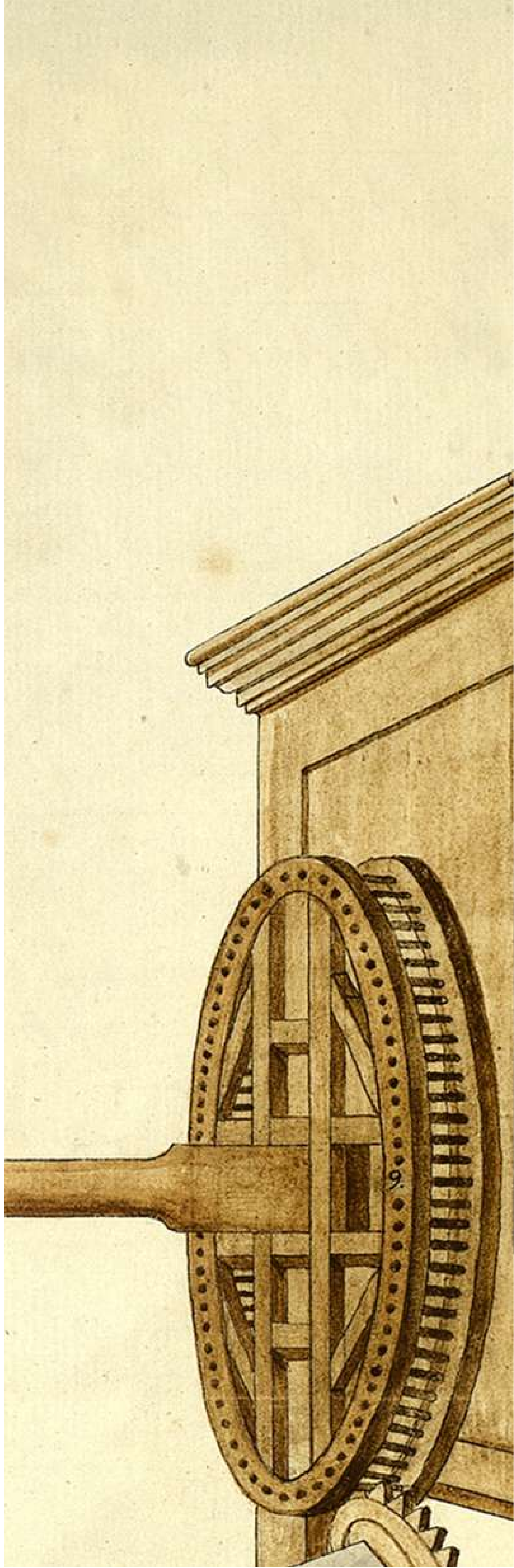
Graphic and planimetric analysis of the quicksilver mine of Huancavelica in Peru.1742.Esteban Oliva.Facsimile reproduction.Minas de Almadén y Arrayanes S.A. (MAYASA).Board of Directors' Room, Madrid, Spain.

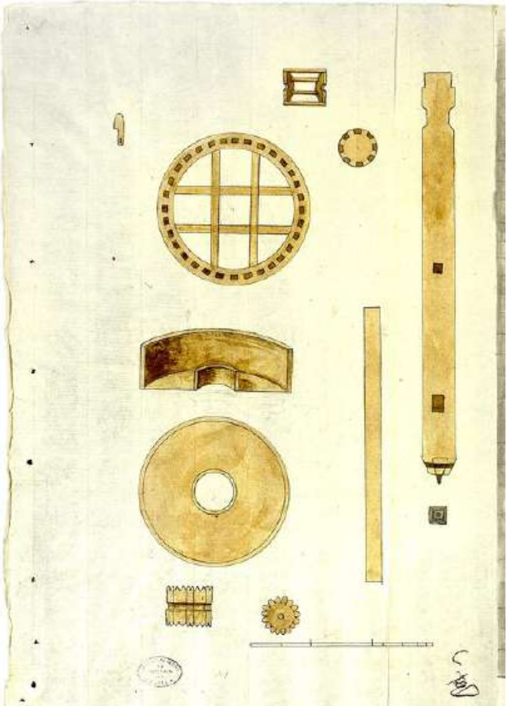
6. ENGINEERING AND INDUSTRY

The relationship between engineering and industry constitutes one of the most significant processes of knowledge transfer, a two-way exchange crucial for economic development and the consolidation of societies. Much like there was a pre-engineering phase based on craftsmanship and experience, there was also a pre-industrial era grounded in craftsmanship. Both evolved, incorporating scientific foundations, transitioning from versatility to specialization, until the disruption brought about by the institutionalize of technical education and the industrial revolution.

The new Spanish territories in the Americas and the Pacific region became a large-scale laboratory where a significant portion of theoretical frameworks and practical applications developed in Europe since the 16th century, and known as the Scientific Revolution from the 17th century onwards, were tested. However, in certain areas inhabited by pre-Columbian cultures, these applications were enriched with the rich local knowledge.

Over four centuries, overseas territories witnessed the development of inventions, innovations, and technologies resulting from the constant exchange of people, products, artifacts, and ideas between Europe and the New World.





Perspective of the machine for sifting flour and kneading bread, invented by Francisco Antonio de Horcasitas, in Mexico.1786.Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Ingenios, 193.

Currency, Tobacco, Flour and Bread

Currency: The colonial enterprise required rich minerals, gold and silver, as well as places for minting coins: the Mints or "Cecas." Thus, America soon had its first Mints in Mexico (1535) and Santo Domingo (1536) because the coinage produced in Spanish mints, such as the one in the Mint of Seville (1505), was not sufficient. Following these, others were established in Lima (1565), La Plata (1573), Potosí (1574), Santa Fe de Bogotá (1626), Cartagena de Indias (1630), Cuzco (1697), Popayán (1729), Guatemala (1731), Santiago de Chile (1743), and Manila (1861).

Tobacco: This new "medicine" sparked unprecedented interest in Europe. The world's first tobacco factory was established in 1636 in Seville. In the overseas territories, tobacco was primarily cultivated on the island of Hispaniola. The most outstanding tobacco factories include the Royal Tobacco Factory in Havana in 1717, the first tobacco factory in America, and the Royal Factory of Cigars and Cigarettes in Mexico (1769).

Flour and Bread: The mill is the quintessential machine before the industrial revolution. Spanish mill types, such as the horizontal wheel or "rodezno," powered by water, animals, or wind, quickly made their way to America in the mid-16th century. In America, native inventions allowed for labor savings and increased production. The main challenge on the American continent was the absence of large draft animals, leading to the domestication of the llama, vicuña, and alpaca for this purpose.

Factories in the Philippines: Iron, Gunpowder, Paper, Textile and Dyes

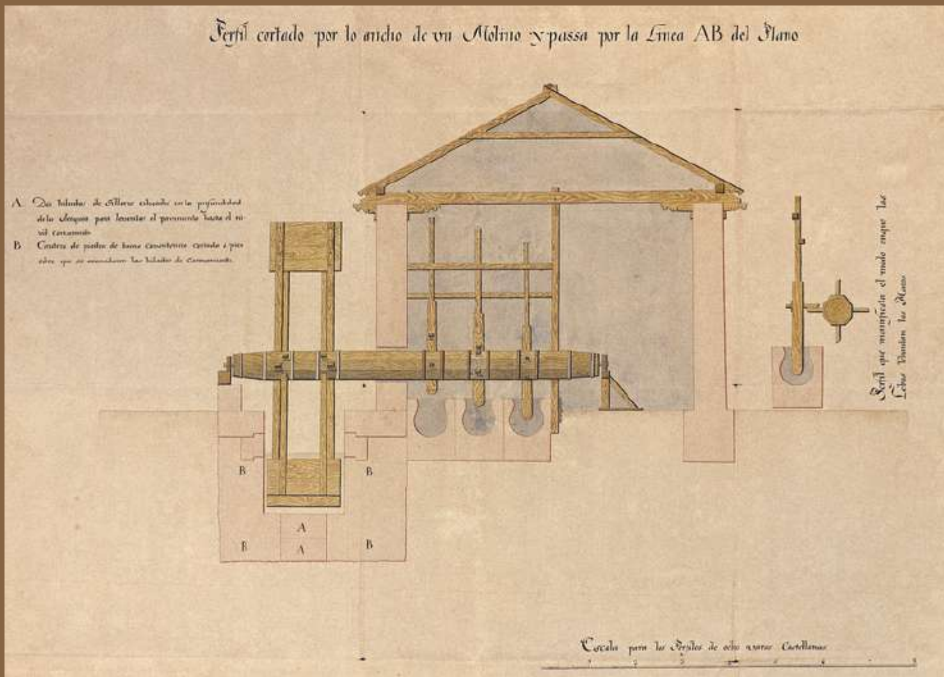
Since the late 18th century and especially in the 19th century, there was an intensification of trade in products from the Philippine archipelago in international markets. This, particularly in the last third of the 19th century, acted as a stimulus for Spanish investments and the establishment of companies and factories under the Law of 1820, a precursor to patent legislation.

Iron: Although of less interest than precious metals, iron was initially used for tools and later in amalgamation. With the 19th-century industrial revolution, the iron industry was limited to non-emancipated territories overseas, such as the Philippines. There, the Tanay factory in Rizal was established, built according to Western standards but used by the Chinese community.

Gunpowder: Due to difficulties in obtaining saltpeter, a component of gunpowder, frequent shipments were sent from the Peninsula to overseas territories. The Villafeliche factory in Aragon, with its hydraulic mills, was the main producer and served as a model for others, such as the San Juan Bautista de Calambá factory in the province of Laguna de Bay (1773).

Paper and textiles: The factories of Domingo Roxas and Ureta played a prominent role. European rag paper was regularly sent overseas and was primarily used for official documents. In 1820, Filipino industrialist Domingo Roxas y Ureta presented a paper-making machine with advanced technology, following Asian industrial traditions. He also introduced a spinning machine that surpassed the techniques of old textile workshops.

Dyes: Annatto, cochineal, dyewood, or Campeche wood, and indigo were overseas dyes primarily used in the textile industry. The trade of the latter two led to competition with the British in Belize, south of Yucatán. In 1777, Francisco Javier Salgado, a resident of Manila, obtained the exclusive exploitation of indigo in his factory in the Laguna de Bay in the Philippines.



Part of the project for the gunpowder mills, warehouses, houses and offices under construction in the Estancia de San Juan Bautista de Calambá, province of Laguna de Bay, after the model of Villafeliche de Zaragoza.Manila, 14 January 1773.Miguel Antonio Gómez, engineer (1731-XVIII); direction of Dionisio Kelly, engineer (1732 - 1798).Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Filipinas, 81BIS.

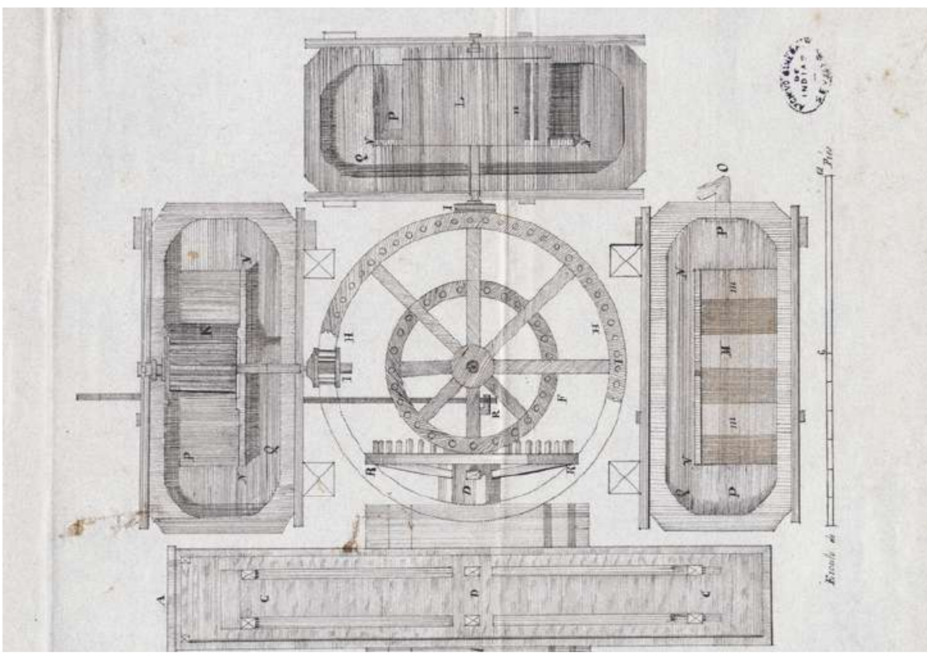
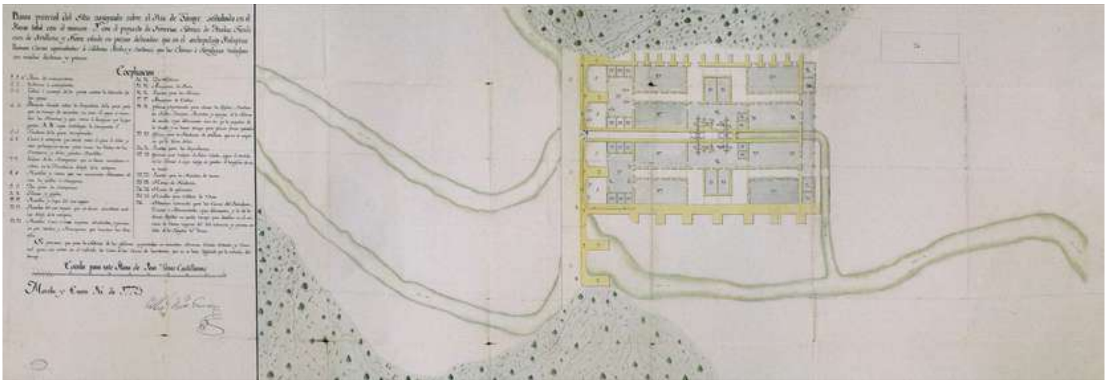


Plate of the cylinder machine to grind the material from which paper is made in the factory purposed by Domingo Roxas y Ureta, Filipino Creole industrialist (1782 - 1843).1822.Facsimile reproduction. General Archive of the Indies, Seville, España. MP-Ingenios, 108A.



Partial plan of the site assigned on the Tanay River, with the project of Ironworks, Anchor Factory, Artillery Foundry and Ironworks.Manila, 16 January 1773Miguel Antonio Gomez, engineer (1731 - f.s. XVIII).Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP-Filipinas, 84.

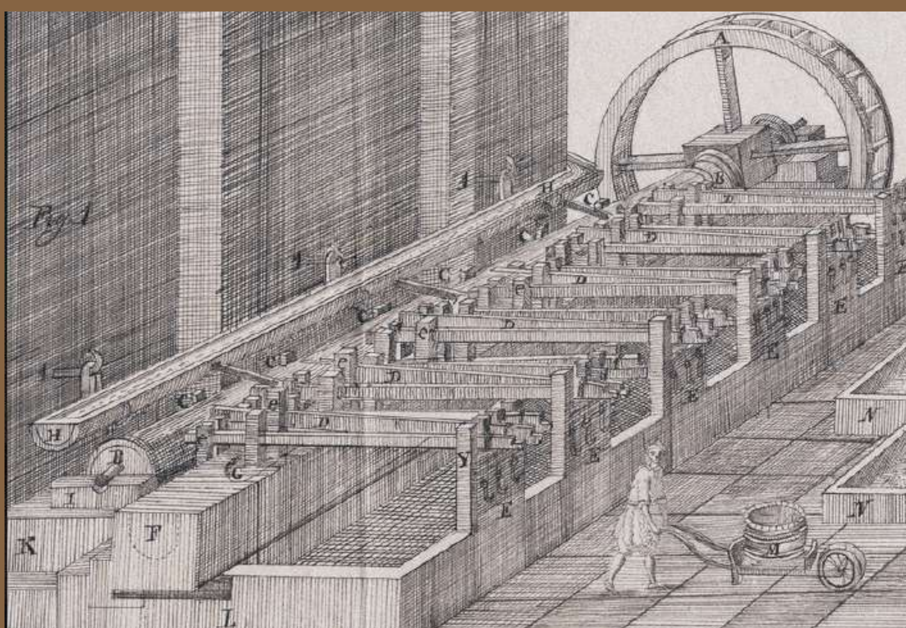
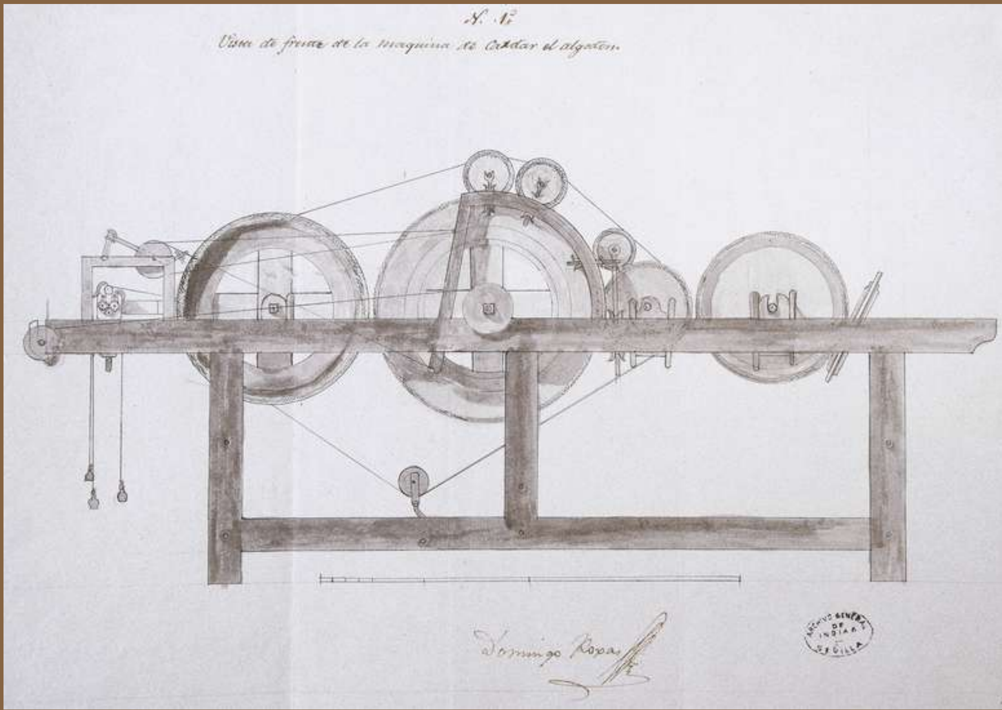
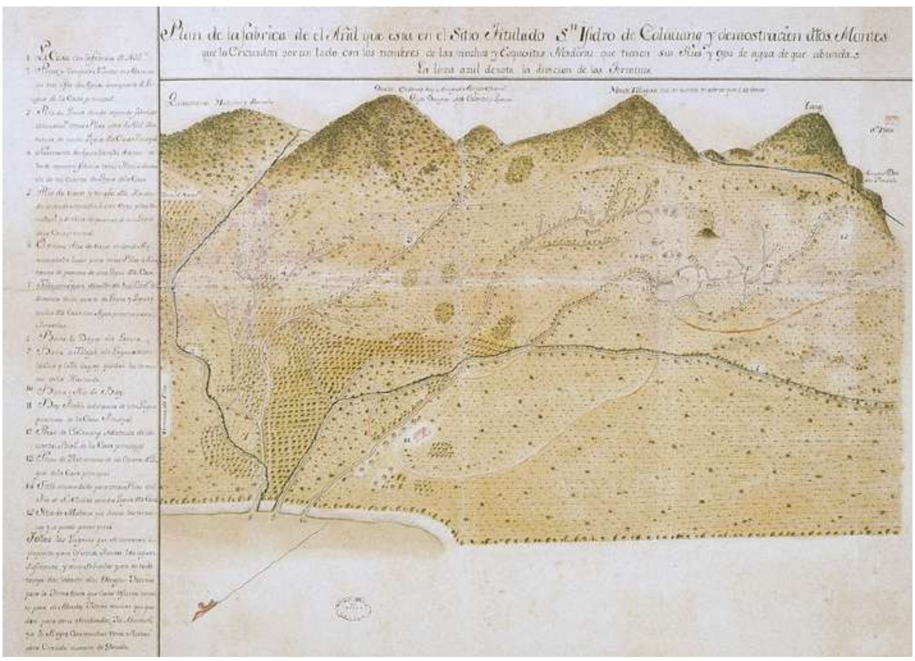


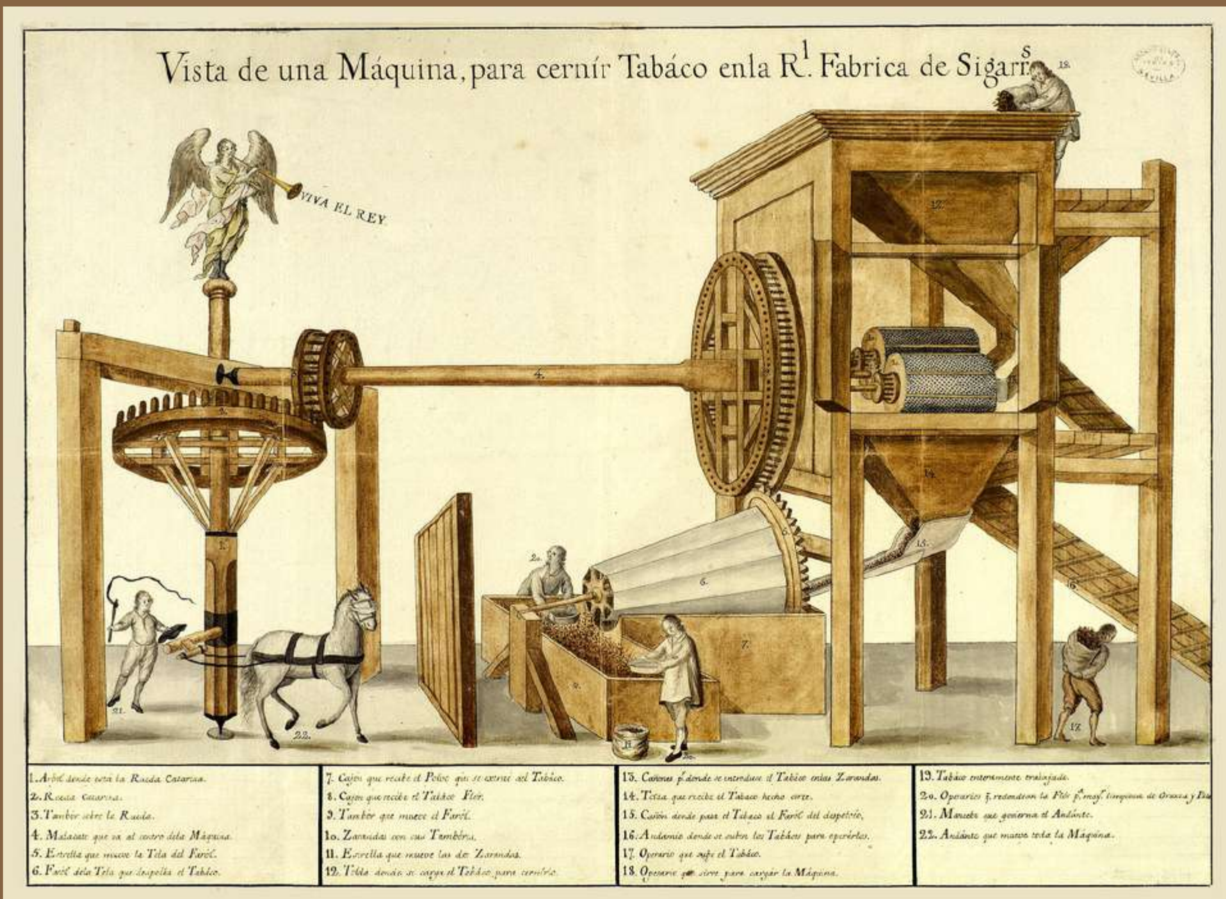
Plate of the mallet machine to grind the material from which paper is made in the factory purposed by Domingo Roxas y Ureta, Filipino Creole industrialist (1782 - 1843).1822.Reproducción facsimilar.Archivo General de Indias, Sevilla, España. MP - Ingenios, 108B.70B



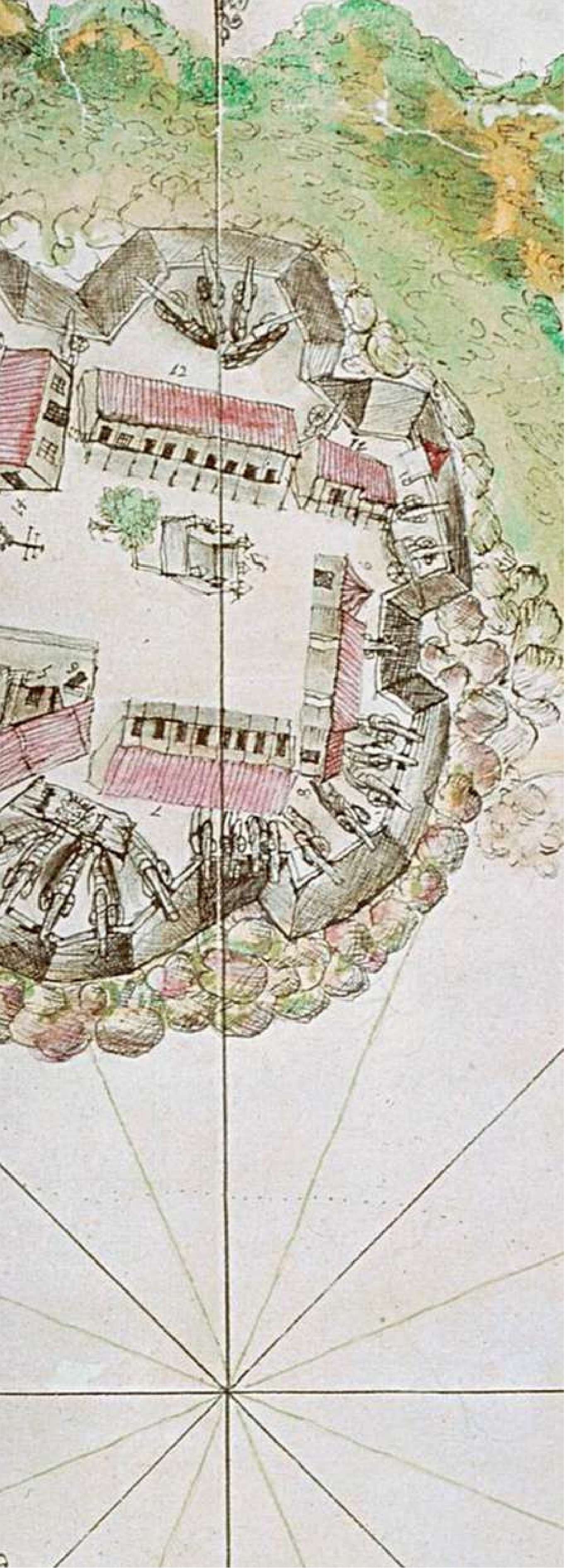
Cotton carding machine proposed by Domingo Roxas and Ureta, a Filipino Creole industrialist, to take advantage of the quality of the cotton from the islands.29 October 1822.Facsimile reproduction.General Archive of the Indies, Seville, España. MP-Ingenios, 110.



Site of San Isidro de Calauang and neighbor mountains where the rivers, waterholes and dams are located to supply the planting of indigo plants and the work of the factory proposed by Francisco Javier Salgado, resident of Manila, according to the model of Guatemala.9 May 1783.Reproducción facsimilar. General Archive of the Indies, Seville, España. MP - Filipinas, 122.



Tobacco sifting machine in the Real Fabrica de Cigarros de Orizaba, Mexico, first one having mechanized machinery manipulated by five operators and moved by animal traction.1787.Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Ingenios, 162.



7.PORT ENGINEERING AND DEFENCE

Maritime communications between the overseas territories and the metropolis fueled the development of coastal cities that served as terminals for the Spanish treasure fleets. These cities benefited from the trade and transportation of gold and silver.

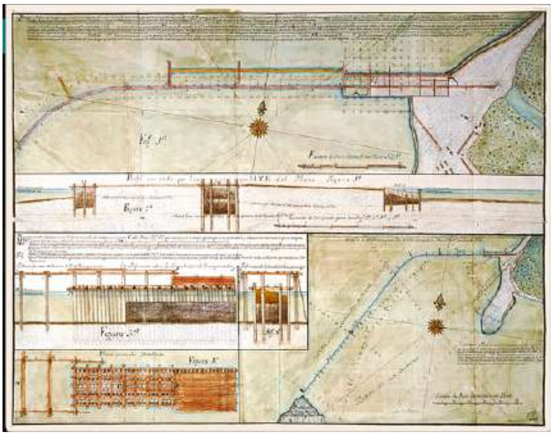
The established port network in the Americas played a crucial role in the formation and maintenance of the American commercial structure. In the Caribbean and Gulf of Mexico, the port of Havana, a naval base for those seas, became the dispersal hub for the fleets returning to Seville. Veracruz and its port of San Juan de Ulúa, connected to the Fleet of New Spain, ensured the cross-traffic of mercury from Almadén and silver from Mexican mines. In Panama, the Atlantic ports of Nombre de Dios and its successor, Portobelo, linked to the Galleons of Tierra Firme, controlled the transportation of Potosí silver arriving from the Pacific ports of Arica, Lima, and Panama through the isthmus routes. This line also included the port of Guayaquil.

Other ports completed the commercial framework: Cartagena in Tierra Firme, La Guaira and Puerto Cabello in Venezuela, and the port of Buenos Aires, which rose in importance from the 18th century onwards as it took over the traffic of Potosí at the expense of Panama.

In the Pacific, the ports of Acapulco in New Spain, Mexico, and Manila in the Philippines were, for centuries, the avenues of relations with the East, monopolizing a vibrant trade in which Mexican silver played a significant role through the so-called Acapulco Galleon.

Spain's monopoly led to the emergence of smuggling and piracy, prompting the establishment of defense and fortification systems in strategic ports, as well as shelter and protection in coastal structures against adverse elements.

Shelter and Coastal Protection Works



Malecón, under construction on November 11, 1771, for the closure of the Bocagrande canal, entrance to the Bay of Cartagena de Indias, with the sand deposit that the sea has formed with its shelter.Santa Fe, February 28, 1775.Copy by Pedro de Ureta based on the original by Antonio de Arévalo (1715 - 1800) made in Cartagena on December 31, 1774.Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Panamá, 189.

Plan of the square of Manila and its environs, with the dike built to neutralise the progressive silting up of the river port at the mouth of the Pasig River.4 January 1814.Ildefonso de Aragón y Abollado, commander engineer (1760 - ?).Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Filipinas, 133.

The selection of locations for American ports was done by seeking installation inside protected bays and based on the good shelter conditions of the surroundings. However, sometimes for reasons of commercial, military or strategic in nature, locations open to the degrading effects of the sea or winds could be chosen, which required the application of corrective techniques, as outlined in the following cases:

- Erosion of Foundations or Dislodgment: To neutralize this, breakwaters made of rubble on stilts or stakes were used, applied with special machines (stilt-ramming machines); also floating wooden boxes, cages or gabions, etc., as seen in, among other examples, the restoration works of the walls of Cartagena de Indias or in the seawall closure of the Boca Grande Canal in that city, as well as in the breakwaters to create a beach and correct the dislodgment of the wall of Callao, by the cosmographer Pedro de Peralta Barnuevo.

- Silting or Sedimentation Processes: Various types of dredges, such as bucket, clamshell, or grab dredges, were used in the fight against silts. But where it was not feasible, other systems were used, including box and rubble breakwaters, as in the ditch of San Fernando de Boca Chica, in Cartagena de Indias, or channeling dikes in river silting, like at the mouth of the Pasig River in Manila.

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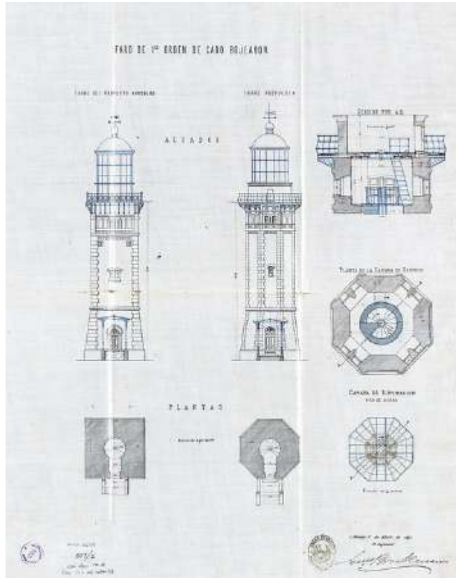
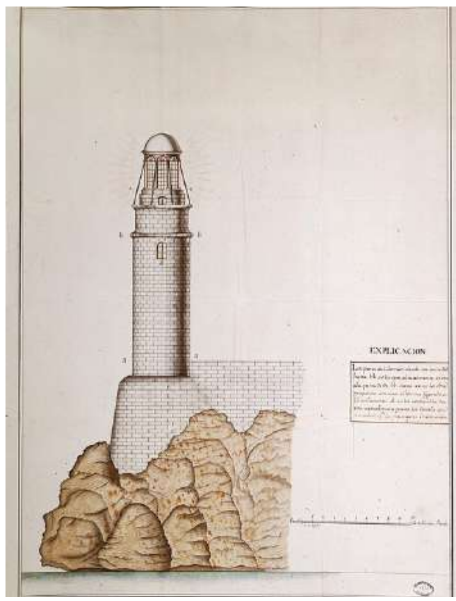
Cape Bojeador First order lighthouse with the proposed and approved tower.1 April 1890.Guillermo Brockman, chief engineer of the Lighhouse services from the archipelago (1856 - 1930). Facsimile reproduction. National Historical Archive, Madrid, Spain. Ultramar, MPD. 6059.



Lighthouses

The use of lighthouses in the New World was a late arrival. In New Spain, the San Juan de Ulúa lighthouse, off the coast of Veracruz, was not built until the late 18th century. Montevideo also had one of the few lighthouses constructed during the colonial period, located on Isla de las Flores, off the coast of the city. On the island of Cuba, the first important lighthouse was installed on the platform of Morro Castle at the entrance to Havana Bay in 1845.

As for the Philippine archipelago, the majority of lighthouses were built after the Lighting Plan of 1885. At the end of Spanish rule, there were nineteen lighthouses of different orders, in addition to fifteen port lights and two lighthouses under construction. The intervention of the chief engineer of the Lighthouse Service, Guillermo Brockmann y Abarzuza, was significant. The typology of lighthouses remained traditional until the introduction of Fresnel lenses.

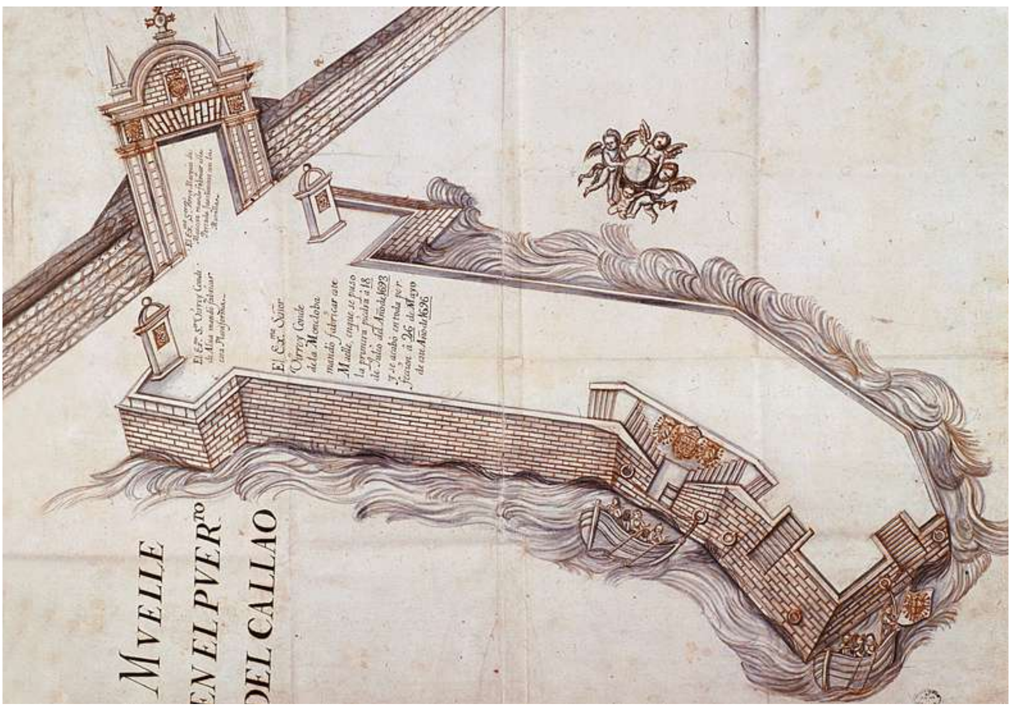


View of Morro Lighthouse, in Havana, that illustrates the project of its regrow with a flashlight to improve the optics and scope.1796.Carried out by the commander of engineers of the square.Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Santo Domingo, 584.

Wharves

The construction of docks in ports for docking ships was also late and an innovation that was only within reach of the most important cities. Very few ports had stone docks, especially in the 16th and 17th centuries. The traditional method for loading and unloading goods was done using small boats. Thus, the stone dock of Callao, built in the 17th century by the Augustinian friar Pedro de la Madrid, stands out. It was equipped with rings similar to those on the wall of San Juan de Ulúa. Despite its solidity, it soon became unusable for deep-draft vessels due to silting and rapid deterioration.

Among the ports that had docks of various utilities are Veracruz (16th century) and Buenos Aires, La Guaira, Puerto Cabello, Marimelena, and Santiago de Cuba in the 18th century. In the 19th century, mention must be made of the San Francisco dock in Havana, designed by Lieutenant Colonel Juan María Muñoz in 1841. Also noteworthy is the construction of the outer harbor of Manila with a large breakwater, a smaller counter-dike, and two basins of different drafts, according to the project by Eduardo López Navarro (1876-1882). In both cases, the use of hydraulic concrete is highlighted, and in Manila, the use of a steam engine for construction and dredging is noteworthy.



Wharf in the Port of Callao by Fr. Pedro de la Madrid (OSA), senior master of the Royal Factories in the Port of Callao. 1696.Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Perú y Chile, 15.

Plan of the inlet and square of Cavite with improvements for its defense.Probable date 11 February 1663. By the engineer Juan de Somovilla y Tejada, based on the plans made by the ducth engineer Ricard Carr and others. Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Filipinas, 8.

Fortified Ports: Defense of America and its Trade

The structure of the commercial monopoly of the Spanish administration in the Overseas Territories, supported by the fleet system, led to the development of smuggling and piracy in the 16th and 17th centuries. Successive involvement of the French, English, and Dutch characterized this period. Faced with repeated attacks, the Crown had to ensure the defense of ports, especially those that had become strategic hubs for transporting royal treasure and commerce. Key ports included the terminals for the fleets of New Spain, the Galleons of Tierra Firme, and the Galleon from Acapulco to Manila. Appropriate fortification systems were implemented to safeguard these ports.

San Juan de Ulúa Island, in front of the town of Veracruz, Mexico, with the existing defense system and the one proposed for its improvement.27 January 1590.Bautista Antonelli, engineer (1547 _ 1616).Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - México, 35.

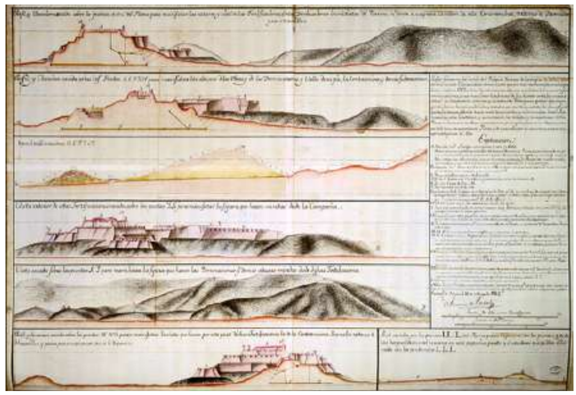
During these centuries, advancements in artillery techniques necessitated the adoption of a new defensive system known as "bastioned fortification." Its application in the Overseas Territories was promoted by Italian technicians in the service of Spain, such as the Antonelli family. Bautista Antonelli, commissioned by Philip II in response to attacks by Francis Drake, developed a strategic defense plan for the Caribbean in 1588. This plan influenced the fortifications of key locations like Havana, Santo Domingo, Puerto Rico, Veracruz, San Juan de Ulúa, Cartagena, Portobelo, and Araya.

The New Thrust of Defense, 18th Century

In this century, military conflicts shifted to the American stage, where British policy is particulary aggressive, waging attacks on Portobelo (1739), Cartagena (1741), and especially Havana and Manila (1762).

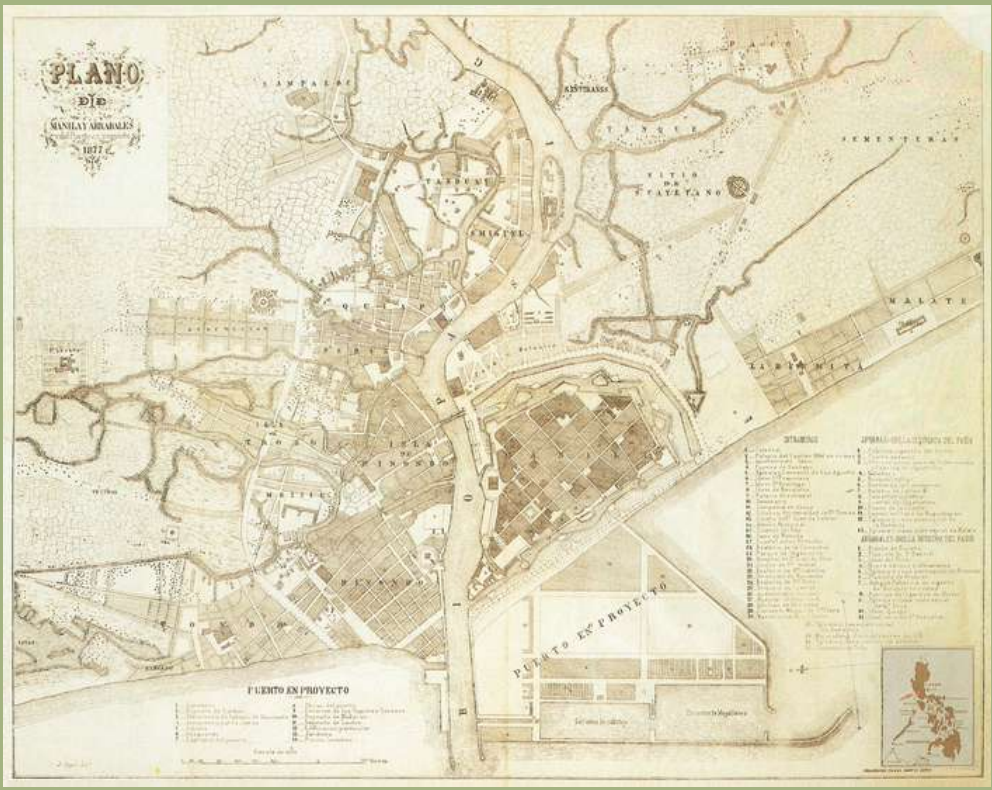
These threats prompted the development of a "Continental Defense Plan," entrusted to engineer Agustín Crame, appointed "General Inspector of the Fortifications of America." His defensive strategy aims to delay possible enemy attacks, impeding their advance by creating permanent obstacles such as batteries, redoubts, trenches, ravelins and casemates.

Crame's plan, with regard to the Caribbean defensive network, led to a massive investment in systems and subsystems. In Havana, this resulted in Silvestre Abarca's projects, including the massive redoubts of La Cabaña, predominantly El Príncipe and Atarés. Similarly, in Cartagena de Indias (Colombia), San Felipe de Barajas was reinforced, among other fortifications. The defenses of Manila and Cavite were also strengthened after the English attack.



Profiles and elevations of the Castle of San Felipe de Barajas, on the Cerro de San Lázaro hill of Cartagena de Indias, of the new works that have been added to it in the year 1762 to improve the city and its defense. 15 May 1763. Antonio de Arévalo y Porras, engineer (1715 or 1717 - 1800).Facsimile reproduction. General Archive of the Indies, Seville, Spain. MP - Panamá, 171.

Plan of the city, port and castles of San Cristobal de la Havana, the fortress of La Cabaña, already completed, and the last project on the hill of Aróstegui. 8 May 1776. Signed by Luis Huet (1721 - 1798) under the direction of the director engineer Silvestre Abarca (1707 - 1784). Facsimile reproduction. General Archive of the Indies, Seville, Spain. MP - Santo Domingo, 412.

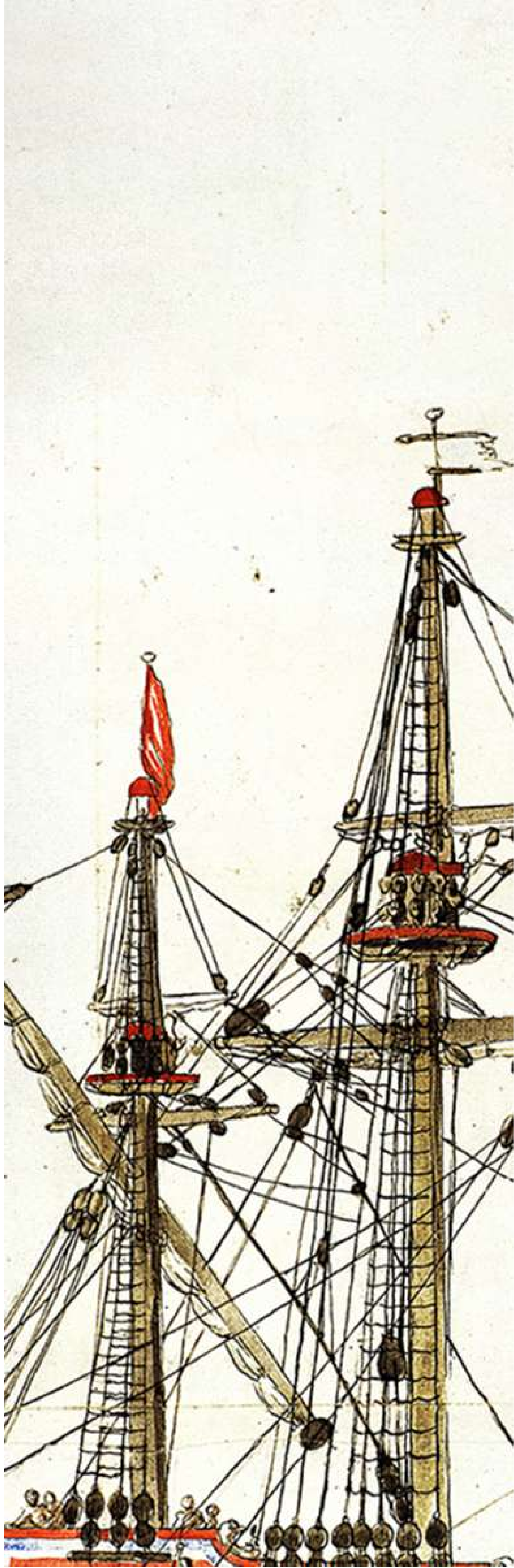


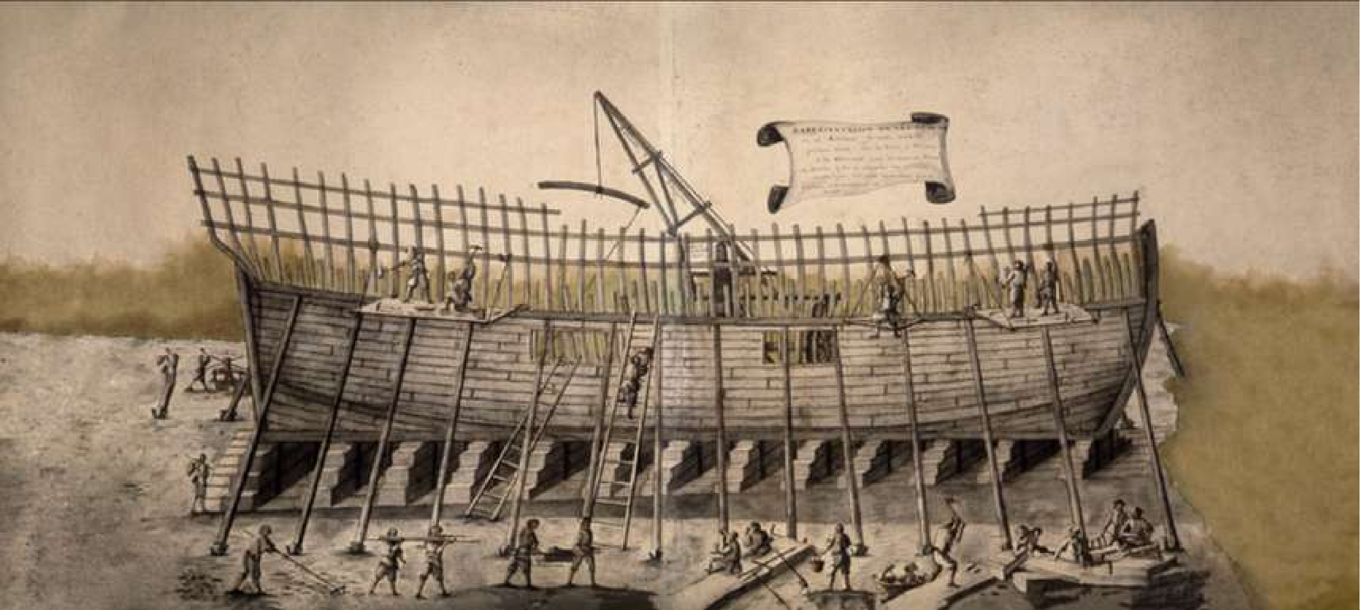
Profiles and elevations of the Castle of San Felipe de Barajas, on the Cerro de San Lázaro hill of Cartagena de Indias, of the new works that have been added to it in the year 1762 to improve the city and its defense. 15 May 1763. Antonio de Arévalo y Porras, engineer (1715 or 1717 - 1800).Facsimile reproduction. General Archive of the Indies, Seville, Spain. MP - Panamá, 171.

8. NAVAL ENGINEERING

None of what has been presented here would have been possible if Spain did not have the naval technology necessary for the numerous and successful expeditions that shaped the territories overseas. Over four centuries of Spanish presence, naval construction transformed from the almost medieval conception of the early ships to the engineering that made possible the manufacturing of the largest passenger and war vessels. It is a continuous and cautious evolution, as the sea poses the dual danger of the waters and enemy ships. From the ship's carpenter, the transition occurred to the naval architect incorporating the laws of mechanics and geometry, and from there to the naval engineer who mastered new disciplines that progress made indispensable, such as metallurgy, thermodynamics, and electricity.

Three types of naval enterprises would determine the class and number of ships: fleets for the Carrera de las Indias, squadrons and flotillas for discovery and exploration expeditions, and those destined for conquest actions. Maritime traffic became the vital artery of the Empire, leading Spain to become the first nation in Europe to produce regulations, instructions, and treaties for naval construction and navigation.





Representation of a frigate in the shipyard: lined up to the first belt,with the wind plates, scaffold, crane or davit for lifting the jibs, etc. 1719 - 1739. Diccionary of all modern naval architecture by Juan José Navarrode Viana y Búfalo, Marquis de la Victoria (1687 - 1772).

Diego García de Palacio (¿ - ca. 1595).Nautical instruction, for the proper use and governance of ships, their design, and management according to the latitude of Mexico.Pedro Ocharte, 1587.Reproducción facsimilar.Naval Museum, Madrid, Spain. MNM CF 136.

Shipbuilding and Ship Maintenance Facilities

The need to create an efficient and powerful Navy led to the establishment of multiple infrastructures dedicated to both ship maintenance and shipbuilding, including rigging, rigging components, canvas, etc. Two main factors determined their location: the proximity of forests with high-quality wood and the availability of sufficient drafts between the open sea and the shipyards. Thus, numerous arsenals and shipyards were founded in the overseas territories: Realejo, Guayaquil, Havana, Veracruz, San Juan de Puerto Rico, San Blas, Cartagena de Indias, Montevideo, and Manila. These complex facilities could bring together up to thirty specialized guilds, considered by some authors as the first industry in Spain.

Technical developments were continuous: slipways, gates for closing arsenals, drainage systems using tidal amplitude or pumps, and machines and devices for the handling and placement of large pieces.

Looking after the maintenance and repair of ships was as crucial as their construction, as the durability of the fleet depended on it. Consequently, numerous facilities were designed and built for hull maintenance, which primarily involved cleaning, replacing worn-out parts, and caulking or waterproofing the hull. Dry-docking methods included using slipways and docks, "keeling over" on a sandy bed and tilting the ship to one side, or even afloat, using large deadweights to heel the vessel.

Diego García de Palacio (¿ - ca. 1595).Nautical instruction, for the proper use and governance of ships, their design, and management according to the latitude of Mexico.Pedro Ocharte, 1587.Reproducción facsimilar. Naval Museum, Madrid, Spain. MNM CF 136.

Ships: Regulations, Technology, Types, and Systems

An unmistakable symbol of Spanish technology, based on a long tradition of Mediterranean coastal navigation and oceanic voyages along African coasts and European seas, shipbuilding evolved from the vessels of exploration, consisting of caravels and naos, to larger galleons and ships intended for the Carrera de Indias. However, for centuries, ship design was influenced by the geographical feature of the Sanlúcar bar that provided entry to the port of Seville, a hub of global trade. Each purpose had its own design, so in addition to the aforementioned ships, vessels were crafted for exploration and conquest with caravels and brigantines, for the Pacific or South Sea with galleons equipped with generous sides, for the Caribbean with frigates and merchant boats, and for settling and trading with the genuine "Spanish galleons." In the 19th century, iron and steam competed against wood and wind, giving rise to the best examples of the latter equipped with technology destined for obsolescence.

Treatises like Diego García de Palacio's and technical instructions from experts such as Antonio Garrote, Antonio de Gaztañeta, Jorge Juan, Francisco Gautier, José Joaquín Romero y Fernández de Landa, Julián Martín de Retamosa in the 18th century, and Isaac Peral in the 19th century, are part of the world heritage in shipbuilding. They designed unique construction systems, representing successive advances in the performance, robustness, and ship's crew.

Map of Manila Bay and Súbic Inlet, discovered by sergeant major José Cortés Monrroy a timber-producing area suitable for the establishment of a dockyard and shipyard and for the construction of ships.15 May 1715.Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Filipinas, 146.

LIST OF EXHIBITION ITEMS

Composition of portraits of the four pioneering military engineers of their time.From left to right: Cristóbal de Rojas (1555 - 1614), José Próspero de Verboom (1665 - 1744), José de Urrutia y de las Casas (1739 - 1803) and Agustín de Betancourt y Molina (1758 - 1824).

Graphic composition based on the "Hydrographic and Chorographic chart from the Philippines". In the insets, scenes of the city of Manila and Cavite.

Old aqueduct and new water conduit from Chapultepec to the city of Mexico, through arches. 11 August 1761. Lorenzo Rodríguez and others.

Detail of the itinerary sketch of the road from Las Piñas to Calamba, a layout that appears to coincide with the current Asian Highway 26, an important transportation axis on the island 1897. Carlos de las Heras y Crespo, commander of engineers (1860 - 1926).

Map of Tierra Firme and its Isthmus of Panama illustrating the interoceanic land communication, where the famous canal was projected.1744. Nicolás Rodríguez, second engineer (f.s. XVII - c. 1751).

Plan of the Lanatin Valley and Iron Mine named Santa Inés, in the terms in which its labor, population, houses, and offices were in the year 1762 was plundered and destroyed. Manila, 1773. Miguel Antonio Gómez, engineer (1731 - f.s. XVIII).

Detail of the malecón, under construction on November 11, 1771, for the closure of the Bocagrande canal, entrance to the Bay of Cartagena de Indias, with the sand deposit that the sea has formed with its shelter. Santa Fe, February 28, 1775. Copy by Pedro de Ureta based on the original by Antonio de Arévalo (1715 - 1800) made in Cartagena on December 31, 1774.

Representation of a frigate in the shipyard: lined up to the first belt, with the wind plates, scaffold, crane or davit for lifting the jibs, etc.1719 - 1739. Dictionary of all modern naval architecture by Juan José Navarro de Viana y Búfalo, Marquis de la Victoria (1687 - 1772).

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Uniform used by the Corps of Engineers.1751.Juan Martín Cermeño (1700 - 1773).Facsimile reproduction.General Archive of Simancas, Spain. MPD. 15, 055, 01.

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Manual of the engineer. Summary of most of the elementary knowledge and of application in the professions of the engineer and architect. Atlas of 103 sheets. J. Dumaine. Paris 1859, V. 2 Nicolás Valdés y Fernández, lieutenant colonel of engineers (1819 - alive in 1867). Daniel C. Zuellig Collection, Manila, Philippines.

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Measuring ruler with Burgos yardstick scale. [n.d.] J. Rabone & Sons.Bone and metal, circa 16 x 3 cm. Pablo Sánchez de Mora y Pérez Collection, Malaga, Spain.

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Miniature of the gala uniform of civil engineer that belong to Agustín de Betancourt. 20th Century Created by the Collage of Civil Engineers of Roads, Canals, and Ports. Juan Camacho Martínez Collection, Malaga, Spain.

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Map of the curates of Tonalá and San Pedro Tlaquepaque and their district, in New Spain, present-day Mexico. Tonalá, 23 November 1772. Facsimile reproduction. General Archive of the Indies, Seville, Spain. MP - México, 285.

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Design of the new city of Veracruz, projected on the site of the Ventas de Buitrón, and on the road from there to Mexico.28 February 1590. Pedro Ochoa de Leguizamo, engineer (2nd half of the 16th century - beginning of the 17th century?).Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - México, 38.

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The City of Havana, the naval base of the Caribbean, with demarcation into parishes within its semi-irregular layout. Circa 1691. Juan de Císcara y Ramírez, engineer (1671 _ 1720 approximate). Facsimile reproduction. General Archive of the Indies, Seville, Spain. MP - Santo Domingo, 97.

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Form and layout of Mexico City, capital of New Spain.1628. Juan Gómez de Trasmonte (c. 1595 _ 1647). Facsimile reproduction. General Archive of the Indies, Seville, Spain. MP - Impresos, 22.

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Plan of the City of Lima, capital of the Viceroyalty of Peru, and its fortifications. 14 October 1687. Pedro Nolasco (O of M), executed on the original by Juan Ramón Connick. Facsimile reproduction. General Archive of the Indies, Seville, Spain. MP - Perú y Chile, 13.

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Plan of Mexico City divided into barrios or quarters for better organization. Mexico City, 12 December 1782. Manuel Villavicencio, engraver (fl. 1753 - 1818). Facsimile reproduction. General Archive of the Indies, Seville, Spain. MP - México, 387.

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Main square map of Panamá City, decked for the king Fernando VI proclamation. 1748. Facsimile reproduction. General Archive of the Indies, Seville, Spain. MP - Panamá, 144.

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Plan of the Convent of the Carmelite Nuns of San Rafael and its surroundings, built in the neighborhood of La Cañadilla, in Santiago de Chile direct supply from the Mapocho river.1773.Facsimile reproduction. General Archive of the Indies, Seville, Spain. MP - Perú y Chile, 257.

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Land between the city of Santiago de Chile and the Maipo River,with the project of the Maipo or San Carlos Canal from said river to the Mapocho River, in this city. Santiago de Chile, 1 August 1800. Agustín Caballero, engineer (fl. 1796 - 1800). Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Perú y Chile, 141.

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City of Trujillo and the Chimú valley in Perú and the water pipes in the territory. 1760. Miguel Feijóo de Sosa, councilman of Trujillo (1718 - 1791) Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Perú y Chile, 39.

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Plan of Manila and its suburbs with the layout of the water conduit.11 November 1869. Genaro Palacios, chief engineer second class, later first class, director of works in the service of the City Council of Manila (1839 - ?). Facsimile reproduction.National Historical Archive, Madrid, Spain. Ultramar, MPD. 4537.

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Town of Yuririapúndaro and others dependent on it, with the great lagoon sanitized by fray Diego de Chávez y Alvarado (OSA) through the canalization of the Lerma River.1580. Cristobal de Vargas Valadés [attribution] Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - México, 24.

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Plan and sections of the paving and sewers of Havana.10 de julio de 1824. Arsène Lacarrière-Latour, french arquitect (1778 - 1837). Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Santo Domingo, 745.

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Mexico City project with ditches, rivers, slopes and drainages to prevent floods. 1753. Domingo de Trespalacios y Escandón (1706 _ 1777). Facsimile reproduction. Royal Academy of History, Madrid, Spain. Canvas - 36, No 285.

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Discretion of the road, which is intended to be made starting from the Inn of Butron to the city of Mexico. Mexico, 8 March 1590. Bautista Antonelli, military engineer (1547 - 1616).Facsimile reproduction. General Archive of the Indies, Seville, Spain. MP - México, 39.

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Roads from Nueva Valencia and Valldupar to Santa Marta.1767.José Aparicio Morata.Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Panamá, 354.

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Profile and plan of the Santa Bridge: Reconstruction of the bridge projected by José Coquette Gallardo. 28th January 1811.Antonio de Ugartevidea.Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Perú y Chile, 167.

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Plan and elevation of the bridge on the "Road to Asia", from Mexico to Acapulco.28 May 1784.Rafael Vasco, lieutenant colonel of the Asturias regiment.Facsimile reproduction. General Archive of the Indies, Seville, Spain. MP - México, 394.

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Armouring for the bridge of Apurimac.1619.Bernardo Florines, engineer and Diego Guillén, master mason.Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Perú y Chile, 203.

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General railway plan with the layout proposal for the Luzón Island.1876. Eduardo López Navarro, civil engineer, Manila Port director;promoter, Genaro Palacios.Facsimile reproduction.National Historical Archive, Madrid, Spain. Ultramar, MPD. 6908.

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Province of Nicaragua, its lagoon, and its drainage through the San Juan River, where a canal between the mentioned oceans was projected. October 3, 1716. Sebastián de Arancibia, governor of Nicaragua.Facsimile reproduction. General Archive of the Indies, Seville, Spain. MP - Guatemala, 17.

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Plan for levelling the South Sea with the Lake of Nicaragua to stablish a communication canal.1781.Manuel Galisteo, engineer.Facsimile reproduction General Archive of the Indies, Seville, Spain. MP - Guatemala, 465.

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Royal Decree of King Charles I to the governor or judge of residence and to the officials of Tierra Firme so that they may investigate with experts the land between the Chagres River and the South Sea and see how to establish a navigable canal between the two.Toledo, 20 February 1534.Facsimile reproduction.General Archive of the Indies, Seville, Spain. Panamá, 234, L.5, f.143 r-v.

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Interior plan of a mine with its galleries and hand lathes and of the embankment where the Bustamante furnaces are located with their quicksilver pipes, possibly from Almadén. 1752.Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Minas, 57.

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Graphic and planimetric analysis of the quicksilver mine of Huancavelica in Peru.1742.Esteban Oliva. Facsimile reproduction.Minas de Almadén y Arrayanes S.A. (MAYASA).Board of Directors' Room, Madrid, Spain.

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Santiago del Real de Minas azogue oven of Nuestra Señora de la concepcion, in Nueva España, ready to remove the metal without reverb glasses or pots.Santiago 1648.Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Minas, 54.

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Map and general geographic table of the measurements of the mines named Mellado, Saucedo and Quebradilla, in the Real de Guanajuato, their mouths, posts and the workings it demarcates.1704.Facsimile reproduction. General Archive of the Indies, Seville, Spain. MP - Minas, 102.

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**Design of the works for the drainage of the San Juan de Rayas mine, in Guanajuato: Shows the project for the replacement of the manual system of dewatering norias with new platforms with winches moved by animal traction.
27 September 1704.Facsimile reproduction. General Archive of the Indies, Seville, Spain. MP - México, 96.**

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Design of the interior road of the San Juan de Rayas mine, in Guanajuato, for the communication of the pits where the veins were exploited. 27 September 1704.Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - México, 97.

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Villa Imperial de Potosí with its Cerro Rico and the 21 lagoons built in the Cari-Cari and Nicaua mountain ranges that provided the water to move the mining mills. 18th century (ca. 1770). Francisco Javier Mendizábal.Facsimile reproduction.Museum of the Army, Toledo, Spain. Nº 43245.

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New method of working mines in Peru, proposal made by sergeant major Gaspar Sabugo, in the proceed of modernitation of the extraction and refining of metal and systematization of work in underground mineas at the end of the 17th century.1790. Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Perú y Chile, 121.

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Perspective of the machine for sifting flour and kneading bread, invented by Francisco Antonio de Horcasitas, in Mexico.1786.Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Ingenios, 193.

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Plan, prospectus and court of the Royal Mint of Potosí, completed by the Interim Superintendent Don Pedro de Tagle, Oydor de Charcas, in the year 1772.18 May 1773.Reproducción facsimilar.General Archive of the Indies, Seville, Spain. MP - Buenos Aires, 276.

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Tobacco sifting machine in the Real Fabrica de Cigarros de Orizaba, Mexico, first one having mechanized machinery manipulated by five operators and moved by animal traction.1787. Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Ingenios, 162.

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Malecón, under construction on November 11, 1771, for the closure of the Bocagrande canal, entrance to the Bay of Cartagena de Indias, with the sand deposit that the sea has formed with its shelter. Santa Fe, February 28, 1775. Copy by Pedro de Ureta based on the original by Antonio de Arévalo (1715 - 1800) made in Cartagena on December 31, 1774.Facsimile reproduction. General Archive of the Indies, Seville, Spain. MP - Panamá, 189.

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Plan of the square of Manila and its environs, with the dike built to neutralise the progressive silting up of the river port at the mouth of the Pasig River. 4 January 1814. Ildefonso de Aragón y Abollado, commander engineer (1760 - ?). Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Filipinas, 133.

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View of Morro Lighthouse, in Havana, that illustrates the project of its regrow with a flashlight to improve the optics and scope. 1796.Carried out by the commander of engineers of the square.Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Santo Domingo, 584.

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Cape Bojeador First order lighthouse with the proposed and approved tower.1 April 1890.Guillermo Brockman, chief engineer of the Lighhouse services from the archipelago (1856 - 1930). Facsimile reproduction. National Historical Archive, Madrid, Spain. Ultramar, MPD. 6059.

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Wharf in the Port of Callao by Fr. Pedro de la Madrid (OSA), senior master of the Royal Factories in the Port of Callao. 1696.Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Perú y Chile, 15.

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Manila and suburbs with the new port project. J.Oppel Lit., copy by Bernardino de los Santos. 1877. Facsimile reproduction. Navala Museum Archive, Madrid. MN-76-4.

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Havana in perspective with the Castle of the Royal Force and, at the entrance of the port, the Cubo and the Watchtower, future locations of the Punta Fort and the Three Kings Castle of El Morro. January 28, 1567.Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Santo Domingo, 4.

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San Juan de Ulúa Island, in front of the town of Veracruz, Mexico, with the existing defense system and the one proposed for its improvement. 27 January 1590. Bautista Antonelli, engineer (1547 _ 1616).Facsimile reproduction. General Archive of the Indies, Seville, Spain. MP - México, 35.

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New town of Portobelo with its bastions and the castles of Santiago and San Felipe at the bay for its defense. By General Juan Bautista de la Rigada, on a plan made by the engineer and battle general Luis de Vemegas Osorio. 22 October 1688.Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Panamá, 97.

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Acapulco with its town and force of San Diego, on the coast of the South Sea (Pacific Ocean), continental port of the Manila galleon line. March 2, 1730 Francisco Álvarez Barreiro, military engineer. Facsimile reproduction. General Archive of the Indies, Seville, Spain. MP - México, 125.

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Plan of the inlet and square of Cavite with improvements for its defense.Probable date 11 February 1663. By the engineer Juan de Somovilla y Tejada, based on the plans made by the ducth engineer Ricard Carr and others. Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Filipinas, 8.

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Plan of the city, port and castles of San Cristobal de la Havana, the fortress of La Cabaña, already completed, and the last project on the hill of Aróstegui. 8 May 1776. Signed by Luis Huet (1721 - 1798) under the direction of the director engineer Silvestre Abarca (1707 - 1784). Facsimile reproduction. General Archive of the Indies, Seville, Spain. MP - Santo Domingo, 412.

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Profiles and elevations of the Castle of San Felipe de Barajas, on the Cerro de San Lázaro hill of Cartagena de Indias, of the new works that have been added to it in the year 1762 to improve the city and its defense. 15 May 1763. Antonio de Arévalo y Porras, engineer (1715 or 1717 - 1800).Facsimile reproduction. General Archive of the Indies, Seville, Spain. MP - Panamá, 171.

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Map of Manila Bay and Súbic Inlet, discovered by sergeant major José Cortés Monrroy a timber-producing area suitable for the establishment of a dockyard and shipyard and for the construction of ships. 15 May 1715.Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Filipinas, 146.

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Havana arsenal, with its sheds, stands and buildings for auxiliary work and the conduction of water from a branch of the royal ditch to power the hydraulic saw. 4 de agosto de 1827. Honoratus de Bouyon y Serze, naval engineer (1753 - 1849).Facsimile reproduction. General Archive of the Indies, Seville, Spain. MP - Santo Domingo, 768.

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Diego García de Palacio (¿ - ca. 1595).Nautical instruction, for the proper use and governance of ships, their design, and management according to the latitude of Mexico.Pedro Ocharte, 1587.Reproducción facsimilar. Naval Museum, Madrid, Spain. MNM CF 136.

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Galleon "Nuestra Señora de la Mar", one of the ships of the Armada of General Marqués del Vado, wrecked in the Gulf of Bermuda. It is recorded as being built in accordance with the regulations of the Recopilación de las Leyes de Indias (Compilation of the Laws of the Indies).1695.Facsimile reproduction. General Archive of the Indies, Seville, Spain. MP - Ingenios, 318.

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Plan for the construction of a 60-gun war frigate in Veracruz: Aft view. November 14, 1690. Facsimile reproduction. General Archive of the Indies, Seville, Spain. MP - Ingenios, 13B.

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Descriptions of the main beam and mirror of the entire stern flat until its crowning, profile of the completed side, and plan of a warship capable of mounting seventy cannons.1720. Antonio de Gaztañeta Iturribalzaga, military and naval engineer (1656 - 1728).Facsimile reproduction.General Archive of the Indies, Seville, Spain. MP - Ingenios, 136B.

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Museo San Agustín

CURATORS
María Antonia Colomar Albájar
Ignacio Sánchez de Mora y Andrés

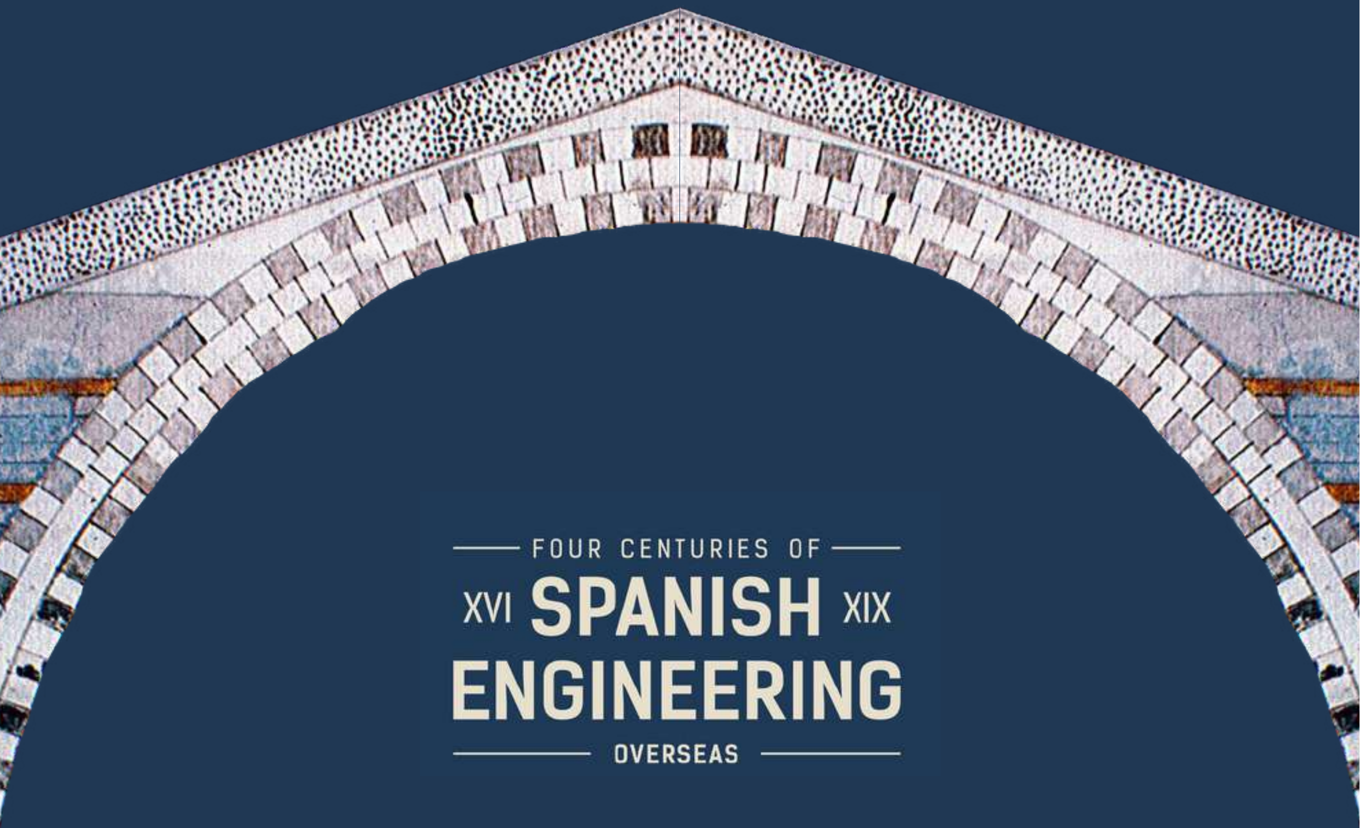
COORDINATION
Embassy of Spain in Manila
Alvaro García Moreno
Pamela A. Bigornia
Paula Gozalvez Jiménez

Museo San Agustin
Rev. Fr. Ricky Vilar, OSA
Louella Revilla

DESIGN AND FACSIMIL PRODUCTION
Tannhauser Estudio
KINKA Graphics

LENDING INSTITUTIONS
Archivo General de Indias, Sevilla
Archivo General de Simancas, Valladolid
Archivo Histórico de la Armada, Madrid
Archivo Histórico Nacional, Madrid
Colección Daniel C. Zuellig, Manila
Colección Juan Camacho Martínez, Málaga
Colección Pablo Sánchez de Mora y Pérez, Málaga
Colegio de Ingenieros de Caminos, Canales y Puertos, Madrid
Minas de Almadén y Arrayanes S.A. MAYASA, Madrid
Colección museográfica de la Academia de Ingenieros de Hoyo de Manzanares, Madrid
Museo del Ejército, Toledo
Museo del Prado, Madrid
Museo Naval, Madrid
Philippine Map Collectors Society (PHIMCOS), Manila
Real Academia de la Historia, Madrid

BIBLIOGRAPHY
"Cuatro siglos de ingeniería española en Ultramar. Siglos XVI-XIX". ASICA - AECID. ISBN 978-84-09-09682-4 (Granada, España, 2019)



FOUR CENTURIES OF

XVI SPANISH XIX ENGINEERING

OVERSEAS