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TECHNICAL-TECHNOLOGICAL AND MATERIALS COMPARATIVE ANALYSIS BETWEEN ITALIAN AND SPANISH MEDIEVAL SHIPYARD (THE CASE OF VENICE AND SEVILLE)

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Abstract: Research on historical dockyards is currently dealt purely from the historical and archaeological point of view, biased to classical examples (Hellenistic *neoria* and Roman *navalia*). The projects are mainly concerned with the analysis of material remains of vessels leaving aside the architectural structures where they actually took shape.

The shipyards experimented their greater typological progress in the Middle Ages, a period in which architecture developed new construction techniques, such as the Gothic style, originally used for cult buildings, were promptly transferred to military structures, as in the case of arsenals in which it was possible to preserve and create more and larger vessels.

These huge monuments, today obsoleted for their original function, are embedded within the fabric of ancient cities with historical harbors and which are involved in recovery and restructuring their urban planning. The research project aims to fulfil a better recording of these structures, from an architectural and engineering point of view, in order to detect the architectonic type, define the traditional construction technics and the employed technologies and identify the used material in relation to the latter; this are indispensable requirements for future recovery interventions of these structures and spaces.

Palabras Clave: Shypyard, Built heritage, Typo-technological analysis, Traditional construction, Valorization.

1. Actual knowledge level about historic shipyards of Mediterranean Sea

In European historical centers, during the last decades of the 20th and 21st centuries, there has been a growing strong sensitivity to the recovery of monuments for museological uses. Walls, fortresses and castles, after centuries of neglect and deterioration, have undergone rehabilitation and restoration processes to be re-converted into new cultural values for cities. For those cities grown around monasteries or convents, the large spaces formerly belonging to them have been converted rather into exhibition centers and civic museums. To follow these socio-political strategies which give them a new function, not only restores the historical architectural fabric, but provides it a central role within the city core, so as to be able to continue its journey along History.

For coastal or riverside cities and, above all, those with harbor facilities, you must bear in mind naval dockyards. All of these impressive buildings, mostly those from Middle Ages, have survived up to current times, have lost their original function and have seen over the centuries change of use of various kinds. They occupy large areas within the maritime town centers and in most cases, until a few decades ago, used to be forgotten pieces of the city. "*These buildings in the loss of their primary function, often results in a loss of perception of their historical role [...] and requires a re-use to new uses in order to implement the preservation of these ancient urban spaces, themselves full of history and memory*" (COLLETTA, 2008).

Although medieval arsenals conform infrastructures of major influence in the Mediterranean, it has not been addressed the issue for their awareness up to day. The study and knowledge of these places have been performed mostly by historians and archaeologists, who so far have rather analyzed the relationship with the port, the trade routes, their impact on military development, focussing mainly on the activities that actually were held inside the yards: construction of boats and their crew, composition of cordage, sails and anchoring elements, as well as the production of artillery etc. Today we know enough about naval engineering, the art of how they produced boats and the technologies involved, but it is necessary to provide a detailed analysis that relates and compares the shipyards where boats came to life, to establish the architectural typology and to understand the importance of these factory buildings. Structures that not only had to be able to contain several mini-workshops, but also to

preserve and repair all types of vessels. Places where cutting-edge technologies were developed and the foundations for the expansion of new trade routes were laid.

Especially in the Middle Ages and later, with the discovery of the new continent, Europe saw a substantial growth and development of these port infrastructures which allowed several powers, both in military and commercial fields, to be able to extend their borders. We perfectly know that the most efficient transport routes were the sea and the rivers and, considering the absence of communication by rail or by air, in the Middle Ages they had to be the only ones. Therefore, they spent enormous energies to fully know, design and build both vessels more and more advanced and able to reach unexplored lands, and innovative and impressive spaces such as the arsenals in which construct them.

Many experts have been in the topic, although every one researching a specific matter; the bibliography is therefore extensive but rather sectorial, some of which has come together in conferences and workshops. In one of the latter it was issued a document, directed by *Blackman D.J.* and *Lentini Ricoveri M.C.*, entitled *Ricoveri per navi militari nei porti del Mediterraneo antico e medievale*, which contains the proceedings of a workshop held in Ravello in 2005. In this document classic oriental arsenals are related with central-southern and Islamic ones of medieval date, especially from an archaeological perspective, concluding that the architectural point of view is also necessary, so far as attention is taken not only of the planimetric development but also of elevation and three-dimensionality.

However, so far it has not been produced any bibliographic or digital work that takes fully account of the architectural or engineering point of view, and consequently, of typological evolution, constituent structures, materials and therefore, the techniques and technologies implemented.

The started up research work has the objective of relating all the studies so far carried out in this regard, tracing the history of the naval infrastructure in the medieval period, and thus helping extend the topic by focusing on constructive, typological, technological and materials aspects.

The arsenals that today are expected to or have in progress restoration and recovery processes, are mostly Italian and Spanish. It is the case of the famous arsenals of Venice, perhaps the best known in the world, in which international events like the *Biennale* of Art and Architecture are held; the so-called "Republican arsenals" of Pisa, inaugurated last year and home of a multi-functional center; those of Amalfi, where there is a museum for the city; and the Spanish examples of Barcelona and Valencia, both converted to naval and maritime museums. All these structures can be examples for many other scattered arsenals around the Mediterranean basin. As for example, those of Seville, for years in restoration process and that soon should see the beginning of the recovery work for a new cultural center. Precisely this site may represent an opportunity to observe the transformation from an abandoned building to new pole of attraction for citizens and tourists. A factory place in which we can analyze the primitive structure still standing, the additions and changes performed along almost eight centuries and verify the current status of materials degradation. A factory model from which to start a comparative analysis, both with dockyards that have been recovered already and those which still remain in a state of abandonment.

2. Towards a new tool for the classification of shipyards

To launch a recovery process of these majestic architectures we should perform previously an accurate research aiming at the revalorisation of emblematic places, strategic nodes from which to start a redevelopment domino effect on the environment that surrounds them, and on a more urban scale.

For the documentation of these artifacts they come into play diverse approaches parallel to each other. In the first place it should be emphasized the close relationship of these structures with the water element and, therefore, is of key importance the hydrogeological aspect of the place on which they arise. Secondly, the complex formal and functional changes that have occurred over the centuries have led to complex and interesting overlays that, with the help of archeology of architecture, it is essential to outline and understand. Finally, the construction techniques and the use of materials, both of the primitive structures of the arsenals and those added later as a result of mutations, represent the mere architectural and engineering aspect of the arsenals.

These essential researching and learning phases are a delicate moment, as they embrace many topics that can't be treated separately, but instead there is a need to make them talk and seek the connection points to fully understand the meaning and importance of these architectures.

The purpose of the research, therefore, is to create an analytical document about evolution and consolidation of the shipbuilding architectural type, based on the comparative analysis of the biggest medieval arsenals of the Mediterranean area, in order to provide knowledge for their conservation and recovery.

The research intends to approach three scales of successive analyzes, in an increasing level of detail: individuation of the architectural type derived from the analysis of the formal characteristics and the functional analogies of different emblematic medieval shipyards of the Mediterranean sea; definition of the traditional construction techniques and the technologies used to realize large-scale buildings and finally to identify the materials used with respect to those.

The choice of the Mediterranean area is due to the fact that, from a Eurocentric perspective, it comprised the majority of the world that was known, a scenario that was constantly changing and disputed by the peoples who inhabited it. People who moved both by land and by sea. The Mediterranean coasts were connected to each other by ports seated along the entire perimeter of the basin. In many of them not only docked ships, but there were factory buildings where boats took shape or were simply kept or repaired. Undoubtedly the port cities with a shipyard represented the great political and economic centers of the time, focus of power and wealth, of opportunities and conflicts.

The examined arsenals for comparative analysis are provided with three study areas: the first of a general nature involves the inventory / census and mapping of historic naval yards belonging to the Mediterranean area (divided in turn into classics - before the fifth century - medieval - from the fifth century to 1492 - and modern - since 1492 until 1789-).

The second area limits the field to the medieval shipyards between the Italian and Iberian peninsulas, territories in which coexisted dynamic societies and different cultures that contributed a relevant social and technological advance, territories that look out to the Mediterranean and that dominated to a large extent. We chose these because of their stabilized type, that although repeats that of the classics, it is nevertheless perfecting until becoming the most complete and evolved thanks to the gothic techniques.

Therefore, the medieval shipyards under study for the second area, selected in the Mediterranean area currently belonging to Italy and Spain, are the following six:

- The Italian of Amalfi (south), Pisa (center) and Venecia (north)
- The Spanish of Seville(south), Valencia (center) and Barcelona (north)

The third area, the most detailed and ambitious, considers only the investigation of two of these six naval shipyards: the arsenal of Venice and the atarazanas of Seville. They are contemporary shipyards, born by the hands of two populations with peculiar cultures and with different purposes. The Venetian world is projected first in the Adriatic Sea, expanding successively throughout the eastern basin of the Mediterranean and almost dominating it, influencing the occupied territories and leaving traces of its passage, such as the different shipyards of Greece (Gouvia) or Croatia (Hvar and Zara) built by Venetian artisans. On the other hand, Seville at the beginning of the Middle Ages participates and is projected, impregnated with its Islamic influence, to the Mediterranean world but with the passage of time it also extends towards the Atlantic Ocean.

This is the reason for the election of these two cities. Flagship centers that have played a key role in the history of the Mediterranean, two cities whose shipyards represented their power and reason for being.



Fig. 1 Complete complex of the Venice Arsenal (Google Earth 1500m altitude - September 2017)

Fig. 2 Old dock of Venice Arsenal, about 1200 (Google Earth 500m altitude - September 2017)

Fig. 3 Originally complex of the Atarazanas of Seville, 1252 (Google Earth 1500m altitude - September 2017)

Fig. 4 The seven remaining ailes in Seville (Google Earth 500m altitude - September 2017)

The arsenal of Venice nowadays constitutes an authentic neighborhood of the city, located in the eastern zone, although it has been growing in several successive phases. The oldest part is represented by the *Arsenale Vecchio* (Old Arsenal), which from the beginning was placed around a dock in the Adriatic Sea. Currently, there are still activities related to the manufacture of boats, although only partially; the other spaces, after a long period of neglect and deterioration, are increasingly recovered or in the recovery phase. It is a place in perpetual updating that does not accept defeat, neither temporal nor cultural nor technological.

The shipyards of Seville, of which now only seven ailes remain, are at a crucial moment. After years of neglect they have recently seen consolidation work and previous studies for their restoration and recovery, which, however, are still waiting. The whole complex was constituted by seventeen orthogonal ailes to the waters of the river *Guadalquivir* that in their origin rubbed them. After the cessation of the main function several have been the uses and the changes undergone, some ailes have been transformed and others, unfortunately, have been demolished in the last century. Luckily, there remains a legacy that helps us to explore its history and imagine its splendor.

With the analysis of all these buildings are intended to achieve the following objectives:

- 1. Describe and review the historical evolution of the typology of the classic and medieval shipyards, analyzing the current state of conservation of the main sites (ruin, abandonment, use, reuse), and define the stratigraphies of the construction units to trace their history .
- 2. Determine the strategic choice of the site, in which it was decided to install an industrial establishment with huge dimensions, in relation to urban settlement, and analyze the current urban relationship of the coast (transformation from industrial port to river park or promenade).
- 3. To verify if there is a formal difference between river and maritime shipyards and how the hydrological factors, river, sea or natural basin influence the architectural morphology of these constructions, taking into account even the dimensional characterization in relation to the boats that in them were built.
- 4. To establish a classification of the shipyards according to their typology and constructive technology, characterizing the traditional construction techniques and the peculiar and advanced technological systems used at the time. In addition, identify the formal and functional changes suffered over time.
- 5. Evaluate the limits imposed by a river or maritime environment in the choice of materials, define them and analyze their aging process and / or deterioration.

3. Methodology of the comparative typological and functional analysis of the medieval arsenals

The research work has been divided into phases of analysis, direct and indirect knowledge and development of guidelines. We intend to analyze each shipyard through the approach in the following tasks:

- Task 1: perform a photogrammetric survey and draw constructive details and three-dimensional models to define construction techniques.
- Task 2: draw up identification cards indicating the construction period, the type of program, whether warlike or commercial, the morphology of the territory in which they are located, whether by sea or river port, the effective volumetries compared to the entire surface area that occupied with respect to the urban nucleus, the structure system, etc.
- Task 3: characterize the materials and analyze the chemical-physical characteristics (this task, in principle, is intended for the Atarazanas de Sevilla and where possible). The scientific study of material characterization will be carried out in the *Consejo Superior de Investigación Científicas, CSIC*.
- Task 4: investigate the urban dynamics that lead to the valorization and study of the strategies applied until now and identify the ideal ones for the architectural recovery.

The goal of this research is to put all together the historical, archaeological, engineering, architectural and urban aspects which intervened in the creation of artifacts that have played a pivotal role in the socio-political and economic development of a society, a role they can recover even if it has been lost.

3.1. First step

In the first phase, under development, the objective is to examine in parallel some of the largest shipyards, for example those of Amalfi, Pisa, Genoa and Venice (Italian), and those of Seville, Valencia, Barcelona and Malaga (Spain), including of the Eastern slope, like the Croats of Zara and Hvar and the turks of Alanya.

A first classification has been performed according to the period of construction, the kind of program intended, if military or commercial, the morphology of the territory in which they are located, whether maritime or inland port, the real volume of the premises compared to the entire surface they occupied with respect to the urban core, the structural system, etc.

Depending on whether the city is located along a waterway or directly on the Mediterranean coast, the arsenals can be divided into:

- **Maritime**, such as Barcelona (Fig. 6) on the Balearic Sea and Amalfi (Fig. 5) on the Tyrrhenian Sea.
- **Fluvial**, and of course it is navigable rivers, is the case of Pisa (Fig. 7) over the Arno River and Seville (Fig. 8) along the Guadalquivir;

The choice of location is also the determining factor in the choice of materials and construction techniques to be used for the construction of the structure of the arsenals. It implies, in fact, available raw materials in the surrounding areas, prosperous parts of clay for the production of bricks or natural stone materials with high structural features, that permit the construction of high quality masonry.

Otra subdivisión se ha hecho en función de la ubicación con respecto al núcleo urbano, de hecho, edificados fuera del recinto amurallado, los astilleros ocupan grandes superficies y según su desarrollo pueden repartirse en:

Another subdivision has been made depending on the location with respect to the urban nucleus, in fact, built up outside of the wall fence in respect to the core of the city, the arsenals occupy large surfaces, and depending on their development can be so distinguished:

- Arsenals **perpendicular to the coastline**, divided in their turn into:
 - Built on the *arenile*
 - Built in contact with water
- Arsenals on **wet dock** (natural or artificial)

The first group is defined by those arsenals whose aisles see their longitudinal direction perpendicular to the coastline, or inland waterway or sea (as in the case of Seville and Barcelona, respectively). It is a setting that allow entry and exit of boats taking advantage of the natural slope of the coast. Usually, the ships did not require major maintenance works were standing near the shore and still maintained direct contact with yards, without entering into them. In other cases, the waters lick directly the arsenals structure allowing easy and comfortable maneuvering to boats, eliminating the huge effort to tow the hulls in the transition zone between water and yard. The arsenal of Amalfi according to some

hypotheses intended to have three aisles which stretched toward the coast with the facade in direct contact with the water (GARGANO, 2010), unfortunately has not survived the entire structure, but only the back part. This configuration, however, is still noticeable in the arsenals of Alanya in Turkey, where it is evident penetration in the water of the foundations on which rest the facade arches and the direct contact between the aisles with the sea (JOHNS, 2010).

The arsenals belonging to the second group, on the contrary, elude direct contact with the coast for defensive reasons. In Pisa or Venice, in fact, the shipyards are real productive neighborhoods that possess their own wall fence (GARZELLA, 1987). Wide arches, are the doors through the ships pass without masts, accessing a large pool of water, called dock, around the naves are developed. The docks can arise out of natural bays, where there were primitive ports, or presenting engineering works in order to own shipbuilding facilities more and more advanced and sophisticated.

The classification, however, is detailed in order to analyze the technological systems used for the realization of the internal spaces of the shipyards. The typical technological system of arsenals, according to studies carried out so far, is mainly constituted by a structures that ensures a vertical development, formed by walls marked by arched openings, on which rests a cover system (unique ceiling), generally a double pitch, which can be formed by beams wooden or stone vaulted structures. The essential elements of those structures are basically: piers, flowing directly from foundations, arcs of connection, different depending on the development in the longitudinal and transverse direction; on the arches there is the the roof pitches, more or less sloping.

Regardless of the geographical context, from building materials and the traditional building techniques, in the Mediterranean basin the naval arsenals (built in the Middle Ages) repeat a similar typological scheme. Buildings from purely industrial character, the arsenals are presented free of decorative elements indeed they are characterized by their clear and simple structure that defines impressive spatiality such those of monumental majestic places of contemporary worship.

Tabla 1. Technological, construction and materials classification of the Amalfi, Barcelona, Pisa y Seville arsenals

		AMALFI	BARCELONA	PISA	SEVILLE
Geometric Data	Pier	Rectangular section 1.95m x 1,40m	Square section side of 0,75m	Square section side of 1,25m	“H” section 2,70m x 1,80m
	Longitud. Arch	Span 2,65m	Span 5,40m and rise 2,20m	Span 5,25m and rise 1,25m	Span 8,50m and rise 4,00m
	Aisle	Width about 6,65m	Width about 8,40m	Width about 8,00m	Width about 8,00m
Materials	Bearing Structure	Irregular stone blocks bound together by mortar made up of lime and sand.	Square blocks of good <i>Montjuich</i> stone processing (sedimentary rock).	Solid brick.	Solid brick.
	Roof	Double sloping roof resting on cross vault of irregular stone blocks bound together by mortar made up of lime and sand.	Wooden roof, anchored on the extrados of the transverse arches, consists of longitudinal beams resting on stone corbels.	The original roof was presented a double sloping, resting on the extrados of the arches, with schist plates fixed with nails to the wooden structures.	Roof in original wooden trusses, later replaced by cross brick vaults in some aisles and in others with steel trusses. (PÉREZ MALLAÏNA, 2012, n° 40)
General Structure		Two aisles (<i>domus</i>), each 6,65m wide and long 44,60m, they are divided by 10 piers.	Eight primitive aisles, currently seven because the two in the middle were merged into one, have a width of about 8,40m.	The entire complex still four aisles whose structure is a rhomboid plant of about 40m wide.	The original complex consisted of 17 aisles, nowadays remain only 7, the southern ones.



Fig. 5 Interior of the *Museo della Bussola*, Amalfi arsenal

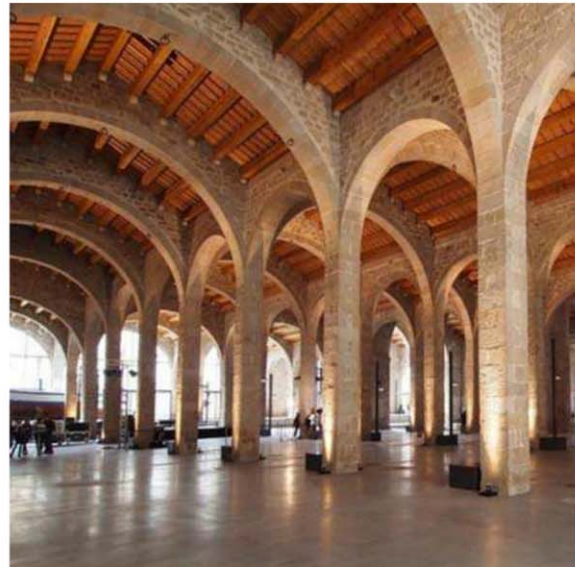


Fig. 6 Interior of the *Museo Marítimo* of the *Reales Atarazanas* of Barcelona

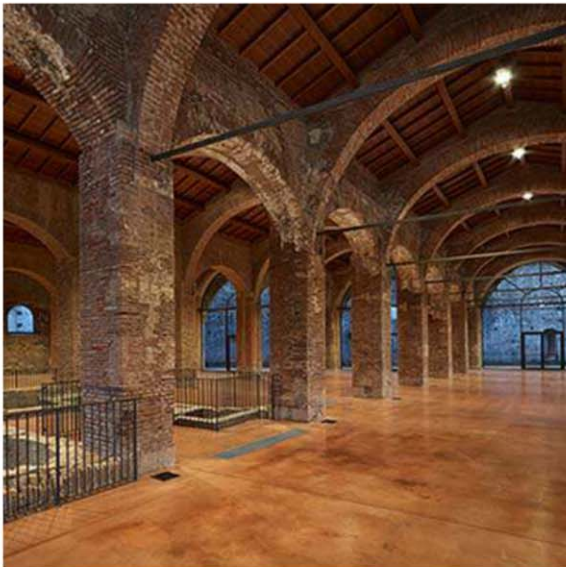


Fig. 7 Recovery of the four aisles of the Pisa shipyard into a polyfunctional center

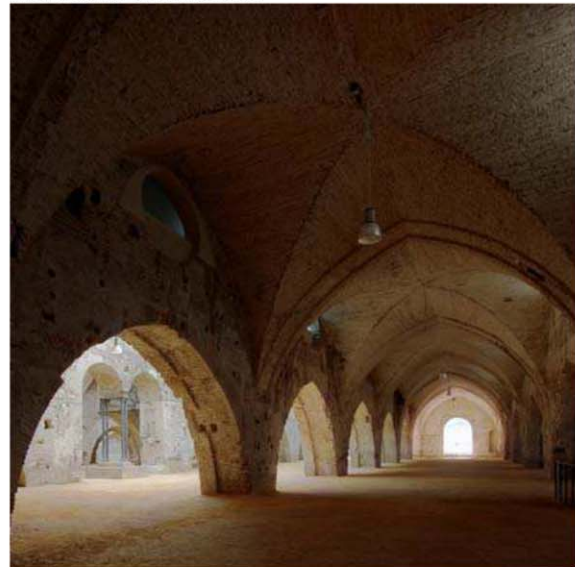


Fig. 8 Aisle n° 2 of the *Reales Atarazanas* of Seville

3.2. Next phase

Next will be occupied the second year in the analysis of the materials. After the first classification, the different materials that compose the structures (natural or artificial stone, mortars, wood or metal elements) will be characterized physically, mechanically and chemically. The specific and innovative construction techniques of the time used will be studied. It will be created a thesaurus with the drawings and three-dimensional diagrams of the construction details, in order to identify similarities or differences between the various techniques used in the building of the shipyards. It will be performed a campaign of fieldwork and diagnostic investigations. A document of historical, typological and material comparative analysis will be drafted, also investigating how the intervention strategies have been used and the strategies for the recovery of medieval shipyards in the Mediterranean until now.

In addition to the historical, architectural and engineering aspects, we will finally investigate urban dynamics that lead to the choice to enhance and restore the medieval naval factories, which role they currently hold within the well-established urban plots and through which strategies to address the redevelopment of specific architectures. Architecture similar to books where you can read centuries of history; each brick is a word, and every element, pillar, arch or vault, are phrases that help us track the pages of intricate and surprising stories.

4. Resultados esperados para la creación de las directrices

Through this research project it will be provide unprecedented knowledge about traditional construction techniques and technologies, devoted to the detailed analysis of the medieval arsenals of the Mediterranean, which can become a useful base for technicians to define an approach to the recovery of this heritage, and aiming to:

- Preserve and protect archaeological sites where naval arsenals are present
- Restore and rehabilitate the industrial structures of naval craft
- Recover the ancient shipbuilding spaces to new uses
- Redevelop the areas close to maritime ports, river and water-front areas
- Help to control and manage the engineering hydraulic interventions near the arsenals

In this case the result of research, beyond an elaborate descriptive section, will present three-dimensional models, both of the shipbuilding complex as a whole and of specific construction details, useful to compare the technological differences and their evolution among the various arsenals. Making use of new techniques of three-dimensional graphic representation, and with the innovative approaches of heritage virtualization, it will develop an interactive tool to be placed in an on-line platform where the user will be able to interact with models, breaking them down to be analyzed in detail.

A virtual and versatile document, easy and intuitive, accessible to professionals who tend to the enhancement and upgrading of the arsenals, and for students who are approaching the study of sciences and traditional techniques.

This research could become an impulse and an inspiration to other studies involved in the same subject, capable of creating in the future a network among many arsenals scattered on the coasts of the Mediterranean Sea, with the aim to create a tool capable of relating medieval seaport infrastructures, triggering a complete process of understanding and awareness of the wider public for these architectures, which in turn made it possible cultural and social connections in the past, comparable to those of the current internet browsing.

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