arquiteturarevista
Vol. 13, n. 2, p. 71-85, jul/dez 2017
Unisinos - doi: 10.4013/arq.2017.132.02

Characterization of a 17th century fort: Case study of the Fort La Planchada, Chile

Caracterização de um forte do século XVII: estudo de caso do Fort La Planchada, Chile

Eric Forcael[1]
Universidad del Bío-Bío
eforcael@ubiobio.cl

Luciano Burgos[1]
Universidad del Bío-Bío
luciano.burgos@gmail.com

Armando Cartes[2]
Universidad de Concepción
acartes@udec.cl

Alexander Opazo[1]
Universidad del Bío-Bío
aopazove@ubiobio.cl

Angela Salinas[1]
Universidad del Bío-Bío
asalinas@ubiobio.cl

ABSTRACT – This article studies the Fort La Planchada, located in southern Chile. Considering the nature of this national monument, the study focuses on the analysis and characterization of its construction aspects: design, geometry, materiality and construction techniques; aspects that are part of the poliorcetics (or military art) perspective. From a methodological point of view, using technical historical resources, reconstruction of the fort under study culminated through a comprehensive literature review and associated fieldwork. The art of poliorcetics and construction techniques, as used by major writers of the 17th century about fortifications and their principles, were applied to the original construction of the fort, considering the difficulties and solutions of its time. The characteristics of the original fort and the analysis of successive reparations revealed the existence of three different designs throughout its history.

Keywords: fort, La Planchada, Chile, 17th century, characterization.

RESUMO – Este artigo estuda o Forte "La Planchada", localizado no sul do Chile. Considerando a natureza deste monumento nacional, o estudo se concentra na análise e caracterização de seus aspectos de construção: desenho, geometria, materialidade e técnicas de construção; aspectos que fazem parte da perspectiva do poliorcetismo (ou arte militar). Do ponto de vista metodológico, utilizando recursos técnicos históricos, a reconstrução do forte em estudo culminou através de uma revisão da literatura e trabalho de campo. A arte das técnicas de poliorcética e construção, usadas pelos principais escritores do século XVII sobre fortificações e seus princípios, foram aplicadas à construção original do forte, considerando as dificuldades e as soluções de seu tempo. As características do forte original e uma análise de reparos sucessivos revelaram a existência dos três projetos diferentes ao longo de sua história.

Palavras-chave: forte, La Planchada, Chile, século XVII, caracterização.

[1] Universidad del Bío-Bío. Avenida Collao 1202, 4051381, Concepción, Región del Bío-Bío, Chile.
[2] Universidad de Concepción. Víctor Lamas 1290, 4070386, Concepción, Región del Bío-Bío, Chile.

Este é um artigo de acesso aberto, licenciado por Creative Commons Atribuição 4.0 International (CC BY 4.0), sendo permitidas reprodução, adaptação e distribuição desde que o autor e a fonte originais sejam creditados.

Historical context of the fort *La Planchada*

Concepción city, the second largest metropolis in Chile, and currently located 500km to the south of the capital (Santiago city), was founded by the Spanish conqueror Pedro de Valdivia in 1550 (Barros, 2000), on the coast of the bay called Penco (original location of Concepción city). The city offered shelter to the ships that reached their shores, where Pedro de Valdivia built his first temporary fortification. After that, in 1557, the Spanish Governor Garcia Hurtado de Mendoza, ordered to build a permanent fort (Campos, 1980). Then in 1574, Governor Melchor Saravia Bravo, modified the construction for military purposes (D'Wartelet, 1863). These first three fortifications are the earliest records in the city's history, revealing the important need to fortify its buildings and protect its citizens (Concepcion during 1550 and 1751, was the capital of Chile).

In Concepción, there was a concern about pirate attacks; however, it was not until the appearance of Spilberg, Dutch pirate, in 1615, that the first port defense arose (Calderón, 1996; Rosales, 1878). Specifically, the military expert Jerónimo de Quiroga built a barbette at the coast, that is, a stone fortification with a set of cannons, fired by artillerymen without further protection (Carvallo, 1875; Fernández, 1979; Guarda, 1990).

The fort was originally named *Battery of Vaults*, then *Castle Fort* and later, *Fort La Planchada*, name by which it is known today. The last name refers to the protection given by a boat dock (Schneider, 1950). In military terminology, the ancient Spanish term "La Planchada" means "flooring to match the deck of a ship and to set the artillery" (D'Wartelet, 1863).

The fort *La Planchada* is the first permanent and solid fortification of Chile, able to avert and resist attacks by sea (Torrejón *et al*., 2002). Despite some discrepancy amongst some historians, the date of official opening of this fort occurred in 1687 (Campos, 1980).

Amadeo Frezier, a French military engineer, encouraged by his scientific pursuits and a royal commission to study the defensive strategies and resources of the region, travelled to Concepción in 1712 (Cartes, 2013, p. 58), stating: "the city is undefended [...] it is observed a barbette at the sea's shore, flanking the berth only, which is in front of the city [...]. The cannons are not in better condition" (Frezier, 1982, p. 60). Figure 1 corresponds to the drawing made by Frezier of the fort *La Planchada*.

Up until Frezier's visit, the fort remained abandoned. Only between 1714 and 1721 there was a renewed interest to restore it, mainly motivated by the increasing risk of indigenous or pirate attacks. Two royal decrees (issued on May 20th, 1714 and on February 26th, 1721), requested to repair the fort. Royal decrees of this type were usually issued by Council Officials or a Superior Court, guaranteeing that a grant or a providence would be implemented (RAE, 2001), in this case, to repair a fortification.

However, neither indigenous tribes nor pirates were factors that would determine the fate of the fort *La Planchada.* Two earthquakes partially destroyed the fort, the first in 1730 and the second in 1751. After the second earthquake, the Concepción city inhabitants relocated 10 km further south in 1764 (Vidal, 1938) thus leaving the fort abandoned.

During the last two decades of the 18th century, there was a renewed interest in improving the fortifications in Chile. Therefore, in 1780, the fort *La Planchada* was renovated, and in 1797 more building repairs were approved (Ossa, 2010).

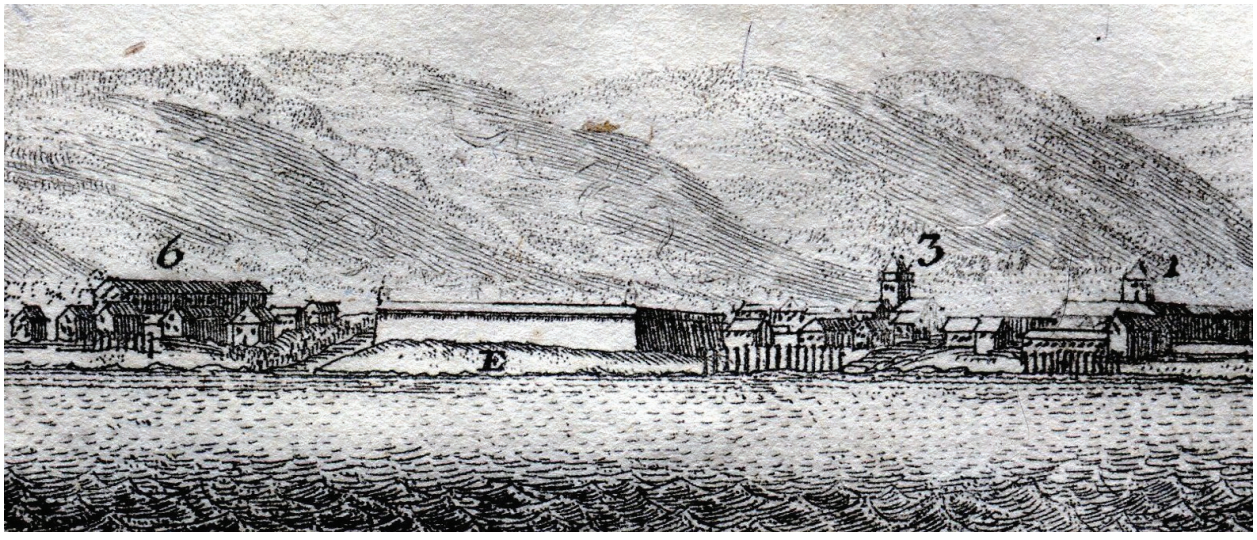

Figure 1. Drawing of the Fort *La Planchada* made by Amadeo Frezier in 1712 (Frezier, 1982).

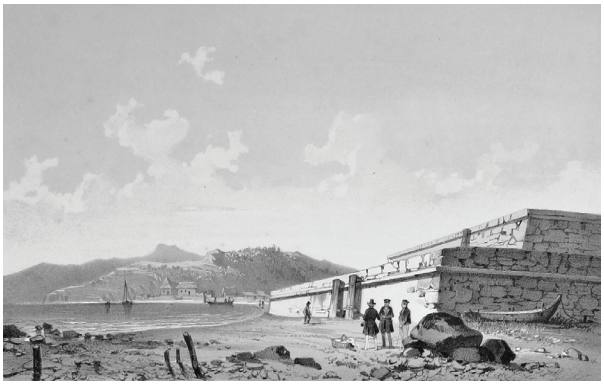

Figure 2. Drawing of the fort *La Planchada* in 1838 (D'Urville, 1842).

Later, in 1838, Dumont D'Urville, French naval officer, explorer and botanist, reached Concepción to visit and draw the old city. He arrived with his cartoonist Le Breton, to gather information about the fort, leading to drawings of the fort *La Planchada* (D'Urville, 1842), as the one shown in Figure 2.

The art of fortification

The early history of construction has been mainly related to magnificent buildings (*i.e.* Egypt, Greece, etc.), dams, roads, and of course, war facilities, whose origins date back as far as to B.C. 4,000 (Gabriel and Metz, 1991). There is a whole theoretical and practical body of knowledge, associated with military engineering procedures and the fortifications, in and around the continent of America. Thus, to determine the construction processes of the Fort *La Planchada*, a brief review on the art of poliorcetics, *i.e.* the art of siege warfare (Alvial, 2003), will be conducted, along with the importance of Vitruvius and construction principles in the 17th century.

Poliorcetics and Vitruvius

Military techniques regarding poliorcetics have a sparse history. In western literature, the oldest available treatise on military tactics is *Poliorcetics or tactical commentary on how to defend from sieges*. Its author is Aeneas Tacticus (4th century BC), who principally talked about: "maneuvers and military procedures relating to the siege of cities and protected sites" (Paniagua, 2007, p. 2). The need to defend the ancient cities demanded well-organized and qualified armies to conduct military operations, which made them able to raise the art of warfare to towering heights (Gabriel and Metz, 1991).

For centuries, techniques learned from the experience of ancient soldiers have been present as the basis of military culture, where learning from weapons, war behaviors, and their fortifications, have served as fundamentals principles for the art of warfare in the contemporary world (Gabriel and Metz, 1991; Ballart and Tresserras, 2001). This interest in the art of warfare remained strong during the middle ages. A widely cited work by writers of the middle ages is the Vitruvian manuscript, discovered in 1415 and printed in 1486 (Nieto and Checa, 2000). The phrase *"firmitas, utilitas, venustas"* (strength, utility and beauty) has been famously repeated by different authors.

During the 16th century, permanent modern fortification bastions emerged in response to gunpowder-powered cannons (Wagner, 2010). The first treatises discussing this concept appeared in France and Spain, where the Monarchy was assisted by Italian engineers in the fortification tasks (Galindo, 1996).

The importance of studying war facilities for the contemporary world

Despite its importance for contemporary times, not always the field of ancient military has been exhaustively explored, ignoring historical evidence about the ability of ancient armies to deploy forces of modern size and to conduct sophisticated military operations (Gabriel and Metz, 1991), in which war facilities (*e.g.* fortifications), played a fundamental role.

In this sense, the fort *La Planchada* is a symbolic representation of a 17th century city's military and maritime past. It is a unique vestige that has survived earthquakes and the passing of time. Its strong presence favors communication, teaching and mediation of historical knowledge, not only onto the local community but also onto visitors and researchers from other latitudes.

On the other hand, the social appropriation and the building of cultural identity by the community around the fort allow, in present time, the promotion of local tourism based on cultural heritage, bringing the well-known benefits associated with managing tourism at heritage sites (Pedersen, 2002).

The basic principles behind the fort construction in the 17th century

In regard to the principles of building forts in Spain during the 17th century, two writers dominate the texts regarding the principles of fort construction and fortifications: Cristóbal de Rojas (1598) and Diego González de Medina (1599).

Reviewing the work of those authors (De Rojas, 1598; González de Medina, 1599) and the fact that they reference to the Vitruvius manuscript, from a construction point of view it can be said that there were three basic principles to building a fortress: (i) determining the construction site, (ii) geometric design, and (iii) construction procedure.

Characterization of the original fort *La Planchada*

Literature review and fort characteristics

As previously mentioned, the art of fortification may vary from country to country and from era to era. Because of culture, regulations or construction methodologies, significant variations are common. However, when characterizing an ancient war facility, there is a number of criteria which remain relatively unaltered, such as: design, geometry, construction, and materials (Gabriel and Metz, 1991; Nieto and Checa, 2000; Paniagua, 2007). Now, because of literature on such criteria is only found amongst a few scientific papers, it was needed to conduct an exhaustive bibliographic review identifying the main technical aspects and characteristics of a 17th century fort. Table 1 summarizes the studies and researches that have considered each of the aforementioned criteria.

Application of Poliorcetics and Vitruvius to the fort La Planchada

Behind the fortifications that arose in America, and particularly in Chile, there is a whole theoretical and practical body associated with military engineering. Undoubtedly, the construction process of the fort *La Planchada* was influenced by the Poliorcetics — *i.e.* art of attacking and defending strongholds (Alvial, 2003) —, the influenced by Vitruvius (Nieto and Checa, 2000), and 17th century construction principles.

Although fortification texts were followed rigorously, military engineers arriving in America had to readapt them, because they usually faced varying onsite conditions (soil, climate, etc.).

Based on the original fort described by Frezier in 1712 (Figure 1), the main aspects considered by its builder Jerónimo de Quiroga were: (i) a glacis with a gentle and clear slope that preceded the moat of the fortress; (ii) a moat built at the foot of the fortress (Schneider, 1950); (iii) construction of a main wall; (iv) proportional escarpment as a response to the use of gunpowder; (v) existence of two bartizans at either ends of the main wall; (vi) cannons mounted on carriages (a frame made of planks and iron pieces placed on wheels, on in which the artillery cannon were mounted), allowing cannon reorientation.

From the Vitruvian perspective (strength, utility and beauty), the fort *La Planchada* is essentially defined by its first two aspects: *strength* and *utility*. The third fac-

Table 1. Authors and Criteria to study and characterize the fort under study.

Authors	Characterization criteria			
	Design	Geometry	Construction	Materials
Beuerman (2009)	•		•	•
Bosiljkov *et al.* (2010)	•		•	•
Calderini (2007)			•	•
Ceroni *et al.* (2009)	•			•
Chávez *et al.* (2012)	•			•
Fernández and Washington (2012)		•		•
García and Meli (2008)	•	•	•	•
Herrera *et al.* (2008)		•		•
Hong *et al.* (2009)	•			•
Ibarra and Barrientos (2011)	•	•		•
Idália *et al.* (2012)				•
Indirli and Apablaza (2010)	•	•	•	•
Lignola and Manfredi (2011)	•	•		•
Meli and Sánchez-Ramírez (2007)	•		•	•
Pecchioni *et al.* (2014)				•
Peres *et al.* (2011)	•		•	•
Pérez-Gracia *et al.* (2011)	•	•		•
Riveiro *et al.* (2011)	•		•	•
Sahady *et al.* (2011)	•	•	•	•
Schueremans *et al.* (2006)		•		•
Sena-Cruz *et al.* (2013)	•		•	•
Silva *et al.* (2010)				•
Solís *et al.* (2012)	•	•		•
Strenchock (2009)				•
Tribulová and Kotlik (2015)				•

tor, *beauty*, initially had no great importance, but in later years, when the perceived danger subsided, there was an attempt to embellish the fort, endowing it the badge of Castile which is visible till this day.

Implementation of the basic construction principles to the Fort La Planchada

Overall, studying the construction of the original fort reflects an adaptation of 17th century construction principles, and construction techniques, in which the Spaniard Cristobal De Rojas is the most followed (Galindo, 1996). From the many treatises written by the author, construction handbooks appeared that allowed making modifications without great mathematical analyses. These handbooks emphasized how to maintain size proportions by listing a body of specifications and prefixed magnitudes.

Each basic principle is thus characterized separately as follows:

Determination of the Fort La Planchada construction site

The location of the fort took place on the shores of the ancient city of Concepcion, Chile (Lat: 36º44'11.70" S, Long: 72º59'45.59" W). The location seems an appropriate choice, by the existence of two water supply streams, protection against land-based attacks, and its stunning scenery.

It had a strategically chosen location, in front of the city and in plain view of the ships that enter that maritime space. A permanent fortress solidly built of stone, in addition to its weapons platform (possibly formed by 16 guns), sought to intimidate or deter any enemy wishing to attack the city. This measure of deterrence was commonly advised by the writers of the time (De Rojas, 1598).

Geometric design of the Fort La Planchada

In the design of the fort, its builder Jerónimo de Quiroga, worked based on the recommendations of Cristóbal De Rojas (1598), occupying the "*Castilian scale*" (a unit of measurement used at that time and continued to be used until the late 19th century, where 1 foot was equal to 0.278635 meters).

With regards to the plant of the fort, its design is simple (Figure 3); to the curtain, *i.e.* main wall, two lateral walls were added. It is shaped like a Gothic *"U"*, with bartizans on either ends of the front wall, according to a fortified bastion style (Wagner, 2010).

According to Salcedo y Pineda and De Santa María (1763), the closed geometry of the fort corresponds to an irregular oblong shape, because the north side wall is not perpendicular to the front wall; unlike the south side, with a right angle in the corner, in which the walls meet (Figure 3).

The outer side of the fort was designed with escarpment. For every X amount of feet — from the wall base — an inward decrease of 1 foot. Writers have found numerous designs of escarpment: 5 to 1, 6 to 1, etc. In the case of *La Planchada*, its embankment is smaller and formed by the natural changes in beach topology (Figure 2). For this reason, a more vertical escarpment was considered. As measured on site, the escarpment used has a ratio of 10 to 1, which considered: climate; proximity to the sea; the inner support embankments; and maneuvering difficulty by attackers. If the wall has a lower escarpment relationship, the rains and winds, which are typical of a

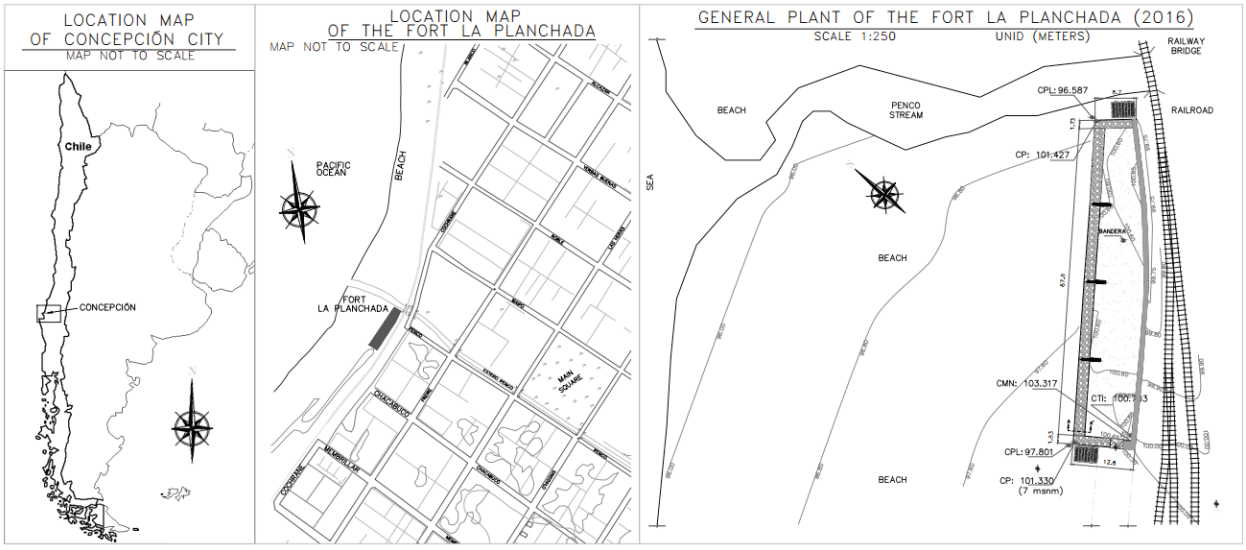

Figure 3. Floor plant of the fort *La Planchada*.

Figure 4. Actual cannon of the fort *La Planchada*, mounted on a wheeled carriage (original wheels were removed) (Cartes, 2013).

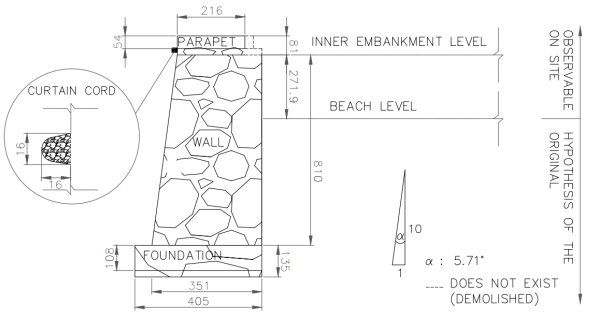

Figure 5. Cross section of the front wall (measured in cm).

coastal climate, could corrupt the wall and facilitate access to the fort by attackers. In a wall that has a higher escarpment relationship, the water flows faster without undermining the construction, preventing the deterioration of the masonry (specifically, the smaller materials that complement the placement of larger stones) and the material that unites the different elements of the wall. In addition, the greater the escarpment gradient, the firmer the construction, because of the accumulating weight of the materials (Galindo, 1996).

From a military point of view, the design analyzed corresponds to a barbette, i.e., a fortification whose parapet (structure that is built on the wall of fortification) has no loopholes nor merlons (openings built into the parapet to introduce the cannon, thus providing protection for artillerymen). Therefore, its gunners were firing without protection but used portable rocks as shielding (Schneider, 1950).

The cannons of the fort *La Planchada*, at the moment of firing over the parapet, were mounted on wheeled carriages (Figure 4) that allowed movement in various horizontal directions.

Dimensions of the Fort La Planchada

While military engineers made regular changes to the dimensions as written in fortification building texts, those changes related to the width of the base of the curtain remained constant, at around 13 feet (De Rojas, 1598; De Cepeda y Andrada, 1669; Galindo, 1996).

Regarding the dimensions of the front wall, the length of the curtain decreases from 350 (which was a common dimension for length at the time) to 250 feet, equivalent to the length of the side having a bulwark. Considering the use of the *"Castilian scale"*, the dimension of 250 feet is close to 35 toesas (a common unit of measurement used at the time; 1 toesa = 1,946m) as described by Frezier in 1712, which corresponds to the 67.9 meters verified on site.

During that era, the height of the curtain of a fort caused deep discrepancies amongst military engineers. A high wall with a weak top renders the moats built around the fortification useless, because the material destroyed in an attack would end up filling the moat. But a low wall could facilitate the use of platforms to access the fortress; considered to be the worst kind of defensive weakness. In face of these discrepancies, De Rojas (1598, p. 69) stated that "the front height should be 40 feet on leveled ground and, in some cases, from 20 to 25 feet in higher places (hills, mountains)". Jerónimo de Quiroga realized that the coast had a natural incline and chose to build the curtain of 30 feet, a height that matches the report by Schneider (1950). The above dimensions can be seen in Figure 5.

The curtain that is still in existence has an average height of 12.5 feet above beach level (3.37 meters approximately, excluding the parapet and the curtain cord). It must be noted that the curtain was preceded by a moat, so the location of the base of the curtain was lower than natural ground elevation, relative to the depth of the moat. Today the moat does not exist (with the earthquakes and tsunamis occurred during the last centuries, it was surely filled in with sand banks or with the glacis itself).

According to the treatises, the curtain cords that topped the walls of a fort were usually a foot high. However, the current cord of *La Planchada* is 0.6 feet high. It is probable that its original height was half of what was commonly utilized during that era (0.5 foot) and that the difference with this measurement (0.1 foot) is due to prior reparations (Figure 5).

The parapet was built on top of the cord curtain. The height of the outer parapet is 2 feet from the cord curtain. The inner parapet is 3 feet from sea level, a measurement that corresponds to the sum of the external parapet (2 feet), the cord curtain (16 cm) and the difference between the cord curtain and the beginning of the escarpment of the wall (10 cm).

The width of the parapet provides less exposure to enemy fire from climbing attackers. According to Salcedo y Pineda and De Santa Maria (1763), the width of the parapet of the original fort was 3 varas (1 vara = 3 feet) and the side walls was 7 (2.25 varas). The current width

of the parapet found in *La Planchada*, is 8 feet for the curtain and 7 feet for the side walls.

The dimensions of the parapet mentioned earlier are smaller than the width of the top of the curtain; a criterion that corresponds to the construction practices and military design of the time. This is because the parapet does not have a support embankment on the inside, for the reason that if it were to be blown up by enemy artillery, rock fragmentation and dispersion would be at its lowest; the converse would render the moat useless.

Inside of the parapet and above ground level, there must have been a solid platform to prevent mobile carriages of the cannons from getting stuck while shooting. The platform must have had a thickness similar to the cord curtain and a width of 7 to 9 feet, in addition to the length of the mobile carriages.

With respect to the lateral walls, they must have had a flat parapet of 4 feet high, along the ridge of the front parapet above-mentioned. The tilt of the front parapet and the horizontality of the side parapets can be observed in Figures 1, 2 and 6.

The interior embankment, meanwhile, should be leveled with the platform. Currently, there is no platform, so the embankment reaches the inner top of the wall. Thus, the height of the embankment has been modified over time.

The construction of the fort La Planchada (construction methods and materials)

Texts about military fortifications emphasized a construction theory that focused on three aspects: foundations; construction of walls and arches; and vaults inside the fortification. According to De Rojas (1598), and applying his theories to the fort *La Planchada*, it can be noted:

(i) Regarding the foundations. Once the site was identified and realizing that the fort would be built on sea sand, a deep excavation was necessary. If the design of the front wall of *La Planchada* had at its base a width of 13 feet, the foundation had to keep that width and add another 2 feet. The depth was 4 to 5 feet; however, because of the moat, as in the case of the fort under study, an extra 2 feet was added. The ground surface had to be tamped and leveled. Thick masonry was then mounted, piled and arranged in order to get a continuous and flat foundation, where the weight of the fortification wall would rest concentrically (foundation shown in Figure 5).

(ii) Existence of rock under the foundations. If rock stratum was found during the excavation of the foundation, there were two options: (i) walls were founded on that rock directly, or (ii) a bed of wood was laid on that rock stratum, with pieces of wood, half a foot thick and length equal to the base of the wall (13 feet), laid adjacent to one another (Figure 7). This bed of wooden pieces was then covered by a layer of lime and sand. Then, another layer of thinner wood was placed perpendicular to those of the first bed to favor their union. Finally, another mix of lime, sand and gravel was poured, until a level surface was obtained. On it, large stones were placed, forming a platform where the wall would rest.

(iii) Presence of groundwater during excavation. One of the difficulties encountered during the digging process when preparing the foundations was the presence of water, which proved hard to extract. This occurred at the fort *La Planchada*. In this case, water was contained by using void boxes made of long and thick stakes, sunk with mallets, with a spacing 1 foot. The stakes were lined with boards tied together, and then the interior material was dug until solid ground was reached, as shown in Figure 8.

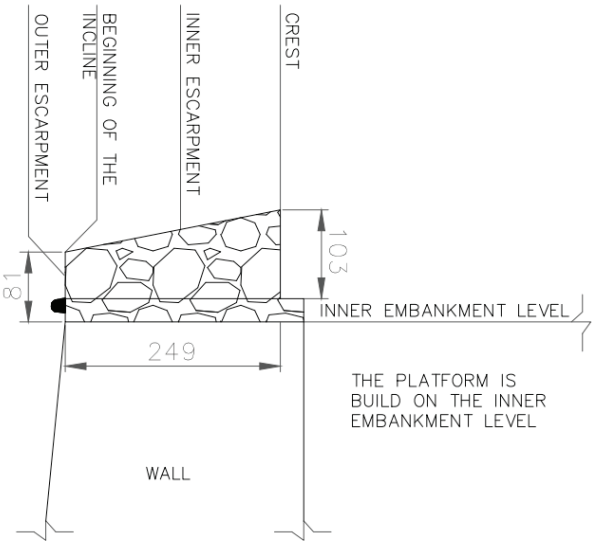

Figure 6. The tilt of the front parapet toward the counterscarp (measured in cm).

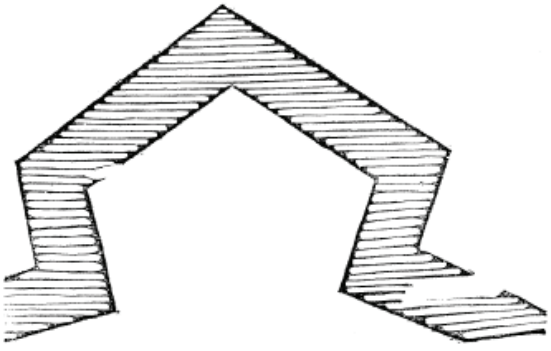

Figure 7. Drawing of the layer of timber used when rock was found under the foundation level (De Rojas, 1598).

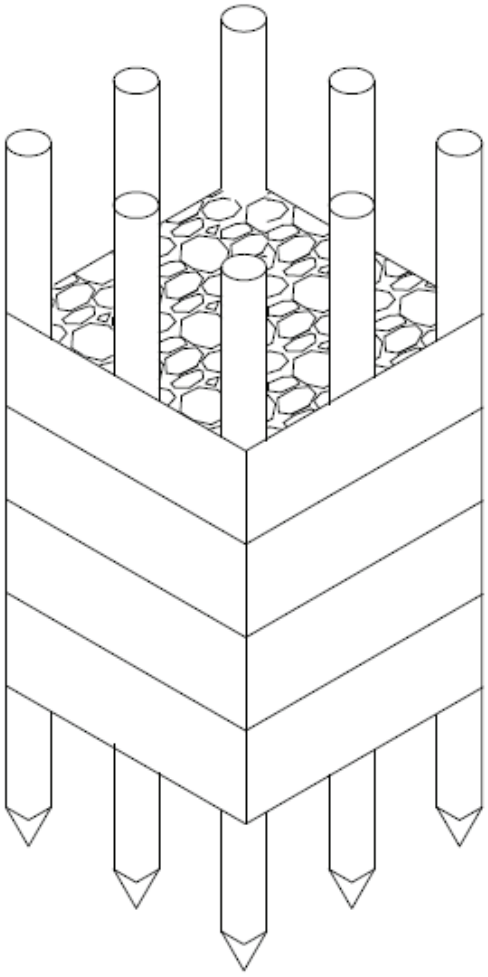

Figure 8. Box used when groundwater was found.

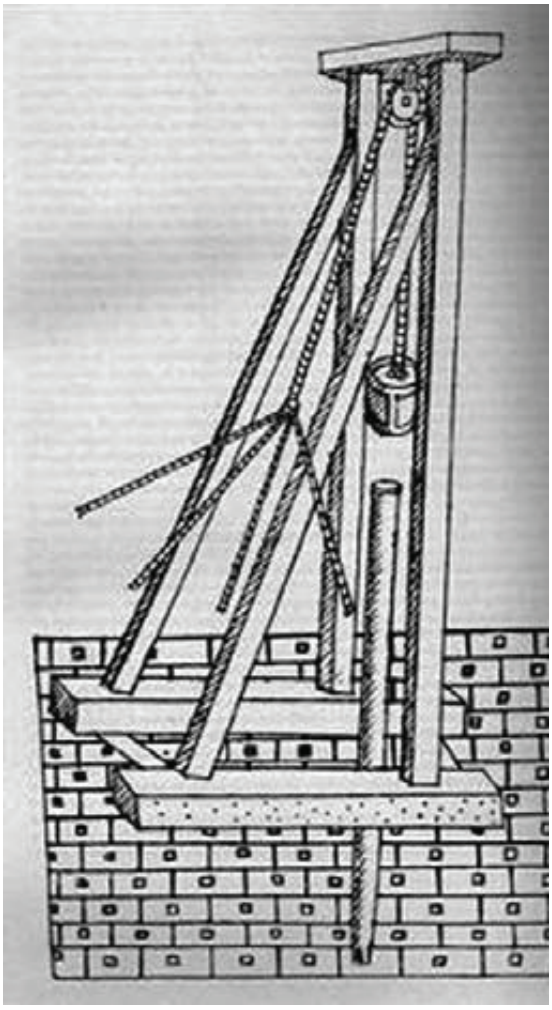

Figure 9. Mechanism to drive piles (De Rojas, 1598).

If when during the excavation the workers did not reach solid ground, a second box had to be built inside of the first one by using the same procedure, but instead with wooden stakes with iron tips. This required a mechanism with a greater striking force than a mallet in order to reach solid ground (Figure 9). Then, the interior material was removed and replaced with lime, along with inter-locking thick stonework (De Rojas, 1598).

(iv) Regarding the materials. Sea sand was only used in the thick walls. In the construction of thinner walls and vaults, quarry sand was used due to its hardness and lime hardening property. River sand was left for plastering and exterior finishing. To deal with moisture and saltpeter present in sea sand, greater amount of lime was added (Palladio, 1998).

To classify the types of sand, there were clear specifications. For sea sand, the procedure consisted of rubbing it between both hands, and if a *"rubbing"* noise was emitted, the sand was classified as suitable; if that noise was not heard, the sand was classified as *"fat of the earth"* (term used in that time), and it was discarded when placed in water, the water became muddied and silty (Palladio, 1998).

The mortar used to bind the rocks of the fort *La Planchada*, utilized lime from pulverized seashells, which hardened in a short time; a construction technique already known in pre-Hispanic America (Antczak and Antczak, 2006). Due to the shortages of limestones, it was a technique used for a long time (Mueller and Kanan, 2005). The lime made from seashells, besides having a higher percentage of calcium carbonate, exhibited important characteristics; it was easy to work with and had weak hydraulic properties that improved durability (Martín, 2001).

As indicated by the writers of that era, the proportion of the mixture consisted of two espuertas (*i.e.* a bucket used at the time) of lime and three espuertas of sand, and by adding fresh water to the agglomerate. The stone was moistened and joined together with the resulting mixture,

(a) (b)

Figure 10. Granite rock (a) and ashlar of limestone (b).

thus forming a poultice like mortar providing adhesion between the two materials.

In summer, due to the heat, the mortar mix faced hardening problems and, to avoid rapid dehydration, a simple solution was to throw buckets of water over the mortar. In winter, however, the ice formed due to low temperatures made it difficult for the mortar mixture to achieve a satisfactory hardening, to which a simple solution was to use fresh lime with little exposure to water (Galindo, 1996).

In the original construction of the fort *La Planchada*, rocks were used on the main wall, side walls, parapet, lace, platform and possibly the ammunition dump. Later, in the new interior constructions as described by Salcedo y Pineda and De Santa Maria (1763), stones, mud (adobe) and sticks were used (Guarda, 1990). In the second half of the 19th century, inner constructions, particularly in rooms intended to be ammunition dumps (also known as Santa Bárbara); bricks replaced the mud and stones.

With regards to the stones used, military engineers knew how to classify them. They were required to be free of saltpeter and caliches, and if the source was not well known, the stones were left under the sun and rain for 8 to 10 months in order to analyze any potential damage.

Observing the fort *La Planchada*, there is a heterogeneity of rocks due to the many reparations done over the years. Despite multiple damage, it is possible to identify and gain access to the most representative rocks located on the outer face of the front wall, deducing that their mineral composition correspond to granite. This rock could be classified as intrusive, with evidence of mica (biotite), plagioclase and remains of millet (Figure 10a), which are in different oxidation states. Another type of rock found in the fort, especially in the corners, is sandstone, corresponding to a sedimentary clastic, or terrigenous detrital rock (Figure 10b), being malleability

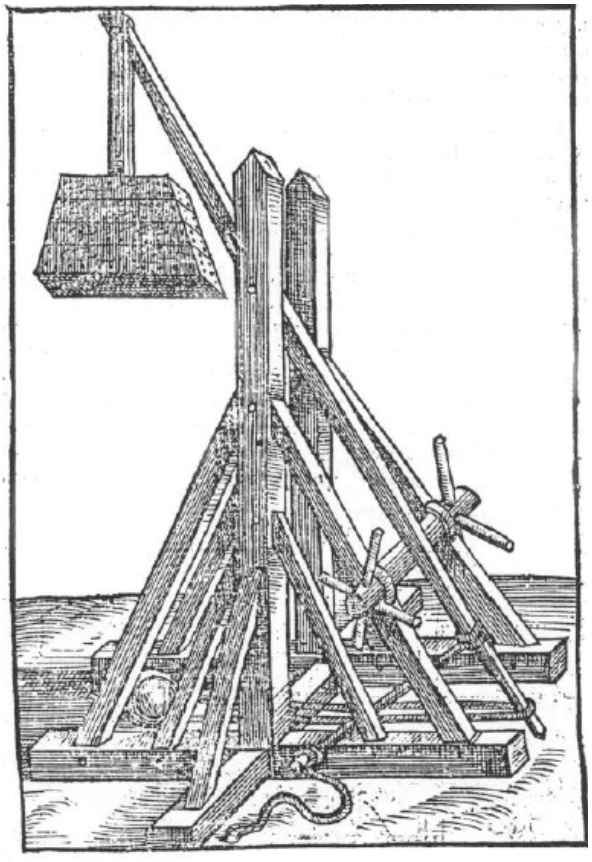

Figure 11. Typical hanger used to lift weights during the 17th century (Galindo, 1996).

its main characteristic. This type of malleable rock allowed easy working and could be cut at any angle.

(v) Construction Technique. On the walls of the fort, ashlars or stone blocks are observed, whose weights

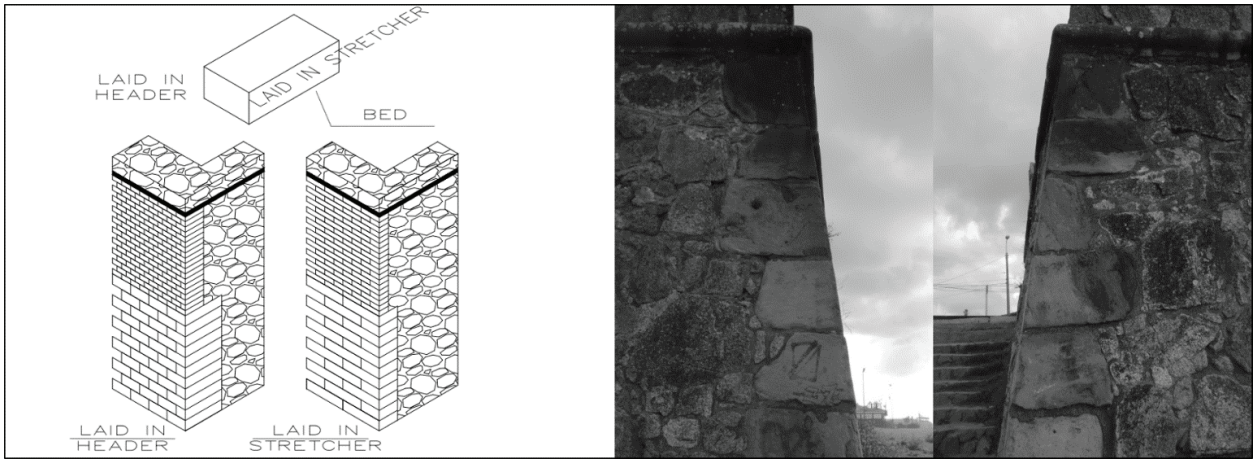

Figure 12. Laying of ashlars: in headers or in stretchers.

and dimensions required handling by specialized hangers (Figure 11). According to the construction techniques of the time, the largest ashlars were placed at the bottom of the wall, a procedure that can be confirmed in the fort *La Planchada*. From the foundation up to the middle of the wall, the largest ashlars were used (each 2.5 to 3 feet long). Subsequent ashlars had to have a front length of 1.5 feet and 1 handspan high; the largest piece that could be used was 2 feet long and one foot high (De Rojas, 1598).

At least three techniques were used when placing the ashlars in the walls: laid in header formation, laid in stretcher formation, and an alternation of both, called stretcher and header formation. The laid in header technique was used when on the exterior wall the smallest face of the ashlar was exposed; the laid in stretcher technique was used when on the exterior wall the largest face of the ashlar was exposed (Galindo, 1996), as seen in Figure 12.

Visually, on the front wall of *La Planchada*, it can be seen that, in general, the largest ashlars have been placed at the bottom of the wall; however, the presence of small rocks, which work as supports for larger ones, is also observed. Mostly, it can be seen that the technique of laying in stretchers was mainly applied in the fort, not excluding the laid in headers technique (Figure 13).

In the main wall (Figure 13), the presence of masonry and small stones hand placed between the interstices of the larger stones are observed. The stones were carved in order to give a uniform surface to the wall, with the aim of impeding the escalation of enemy. All these parts were joined by using a mortar mixture of lime and sand, giving coalescence and solidness to the wall.

In the corners of the wall of *La Planchada*, larger ashlars are found carved on multiple sides, and placed in a vertical row forming the so-called strings. This allowed confining the elements of the walls, providing them with greater resistance (Martín, 2001; Arcos and Porcu,

Figure 13. Ashlars laid in stretchers, not excluding the laid in headers technique.

2003). It is also noted that in placing these ashlars, the laid in stretchers and laid in headers techniques were used (Figure 6).

The fort builders of that time utilized various tools, such as: shovels, picks, hoes, wheelbarrows, etc. such as those shown in Figure 14.

To work at greater heights, the workers would build wooden scaffolding, placed on the floor and independent of the wall. They even used a system called at that time "mechinales" (logs embedded in the wall, on which boards were placed perpendicularly, as shown in Figure 15).

The main wall inside was built vertically, supporting the inner embankment by own weight. The great

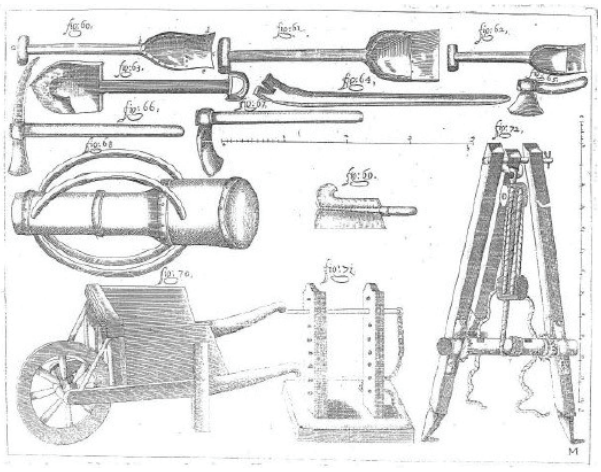

Figure 14. Tools utilized by fort builders during the 17th century (Galindo, 1996; Wagner, 2010).

thickness of the wall prevented tensile stresses (if present, they were negligible). The inner embankment, chosen according to the beach slope, exerted a minimum pressure on the wall, allowing a wall able to resist compressive stresses. Also, the embankment helped to bear the impact of a projectile.

Considering the above technical aspects and that the main occupation of the men of that era was to go to war against indigenous people (Cox, 1998), it can be estimated that the construction of the fort under study took about 3 years, between 1684 and its inauguration in 1687.

It is wrongly assumed that the fort remained unchanged during its history; but it has been transformed. To get a better characterization of it, its main changes over time will be analyzed in the next section.

Analysis and characteristics of transformations of the fort

Transformations experienced by the fort *La Planchada* are identified through direct observations, made by different visitors at different times, and shown in Table 2. On site observations are also included.

Despite the fort faced more than thirty constructive modifications, due to earthquakes or use changes (Burgos, 2014), Table 1 summarizes three main changes. To Frezier, in 1712, the fort consisted of a 67.9 meters long stonewall, with a width of 13.58 meters approximately. He described it as an open fortification, without a countermure inside (Figure 16). In a drawing of the plant of Concepción city (Figure 3), a small extension is seen in the middle of the main wall, which complemented by a drawing of D'Urville (Figure 2), and a description made by the botanists Espinoza and Bauzá in 1789 (Alvial, 2003), would be a staircase descending to a sally-port (*i.e.* door

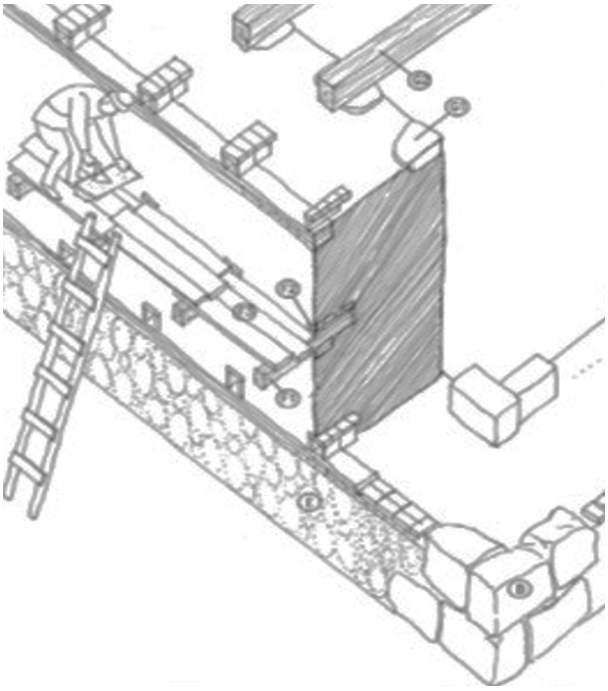

Figure 15. Scaffolding system used during the 17th century called *"mechinales"* (Gil, 2011).

connecting to the moat) located on the front wall. Thus, the fort shown in Figure 16 is the closest description to the original fort.

The following descriptions emerged 50 years later, and belong to Manuel Salcedo y Pineda, Maestre de Campo, and his Colonel Antonio de Santa María (Guarda, 1990). According to their description, the fort had 64.74 meters, dimension that would not match either to the length indicated by Frezier or the current measurements. Its width was virtually doubled (27.39 meters).

With regard to its interior space, Salcedo y Pineda and De Santa Maria (1763) indicate that the fort had a square of 72 x 33 varas across the whole curtain. At that time, there must have been a platform, as already mentioned, which had to have covered the entrance to the sally-port, a situation that Espinoza and Bauzá confirmed in 1789 (Alvial, 2003). It also had two offices built at a lower level of the crest at the front parapet, in the southeastern side of the fort that was used as a gunpowder store, storage and even accommodation. The second room was more spacious, 20 x 6.5 varas, built of sticks and mud. Both units had tile roofing. The above mentioned representation is shown in Figure 17.

Figures 16 (Frezier, 1982) and 17 (Salcedo y Pineda and Santa Maria, 1763) show two quite different fortifications. The open wall built by Jerónimo de Quiroga and described by Frezier was transformed into a closed fort design; then the names *Battery of Vaults* and *Castle*

Table 2. Fort *La Planchada* according to observations made by different visitors at different times.

Reference	Description	Dependencies	Cannons	State
Frezier (1982, p. 61)	Barbette, with haft of the fort without a platform, 35x7 toesas.		Nine in bad state of preservation. Irregular caliber of 24 to 18 pounds.	Bad condition
Salcedo y Pineda and De Santa María (1763)	Oblong with a wall of 78x12 varas, thickness of 3 varas facing the bay and 2.25 varas the others. Total height 5.5 varas. Countermure of 3.5 varas high enclosing the main square 3.5 varas. A rake door southern.	Inner main square of 72x33 varas; offices; ammunition dump of 9.25x5.5 varas; and storage and lodgings of 20x6.5 varas.	Eight iron cannons and nine bronze cannons. Irregular calibers. Mounted on new carriages.	Normal condition
Observations on site (2016)	Main wall of 4,18m high and 67,9m long. Lateral walls of 12,8m (south wall) and 8,7m (north wall), and a new wall of 2.81m high (east).		Three cannons mounted on fixed stone carriages, of 2,26m long.	Normal condition

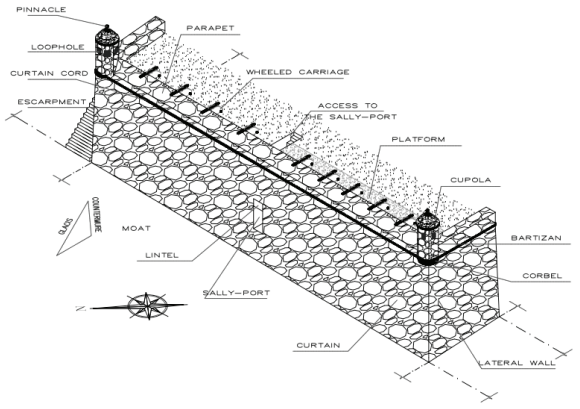

Figure 16. Isometric representation of the fort described by Frezier in 1712.

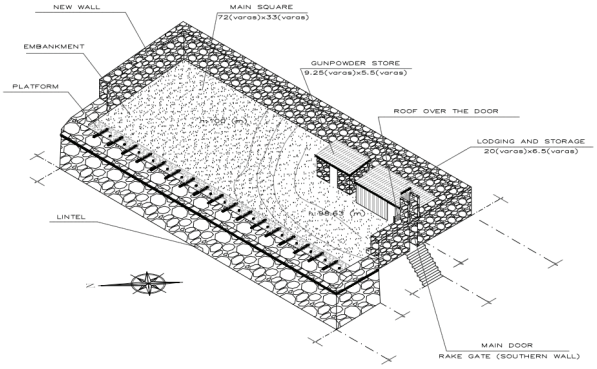

Figure 17. Isometric representation derived from the report by Salcedo y Pineda and De Santa Maria (1763).

Fort are closely related to their previous designs. Later, Thomas O'Higgins, cousin of the Chilean hero Bernardo O'Higgins, evinced in 1797 that the fort served as military personnel barracks and residence (Guarda, 1990).

Hence, between 1797 and 1807 there were three reparations and transformations to the units and buildings in the fort. It is likely that the inner rooms were again refurbished, because seven years after 1807, the Spanish crown transformed the fort into a place for incarceration. Such redesign corresponds to the fort being masterfully drawn by Le Breton, companion of D'Urville in 1838 (Figure 2).

The advent of the railroad and its subsequent expansion throughout coastal villages in 1904, brought about the demolition of 60% of the fortress, especially in its southeastern part (Schneider, 1950). Figure 18 shows this modification, further evidence of a new rear wall as a result of later reconstructions.

If Figures 16 and 18 are compared, it may be noted that the current fort, in general, approaches the original design, except for the new rear wall and the height of the main wall.

Conclusions

As the present research consisted first of an exhaustive historical review of the fort *La Planchada* as a case study of fortifications built in America during the 17th century, and after that as a case study of the characterization of the fort and its constructive aspects, the conclusions are presented addressing both the historical and constructive perspectives.

From a historical perspective

The bibliographical information that allowed writing the literature review for the fort *La Planchada* is scarce and dispersed. Thus, the paper seeks to be a socio-cultural and historical contribution to the patrimonial rescue of construction processes of forts built during the 17th century

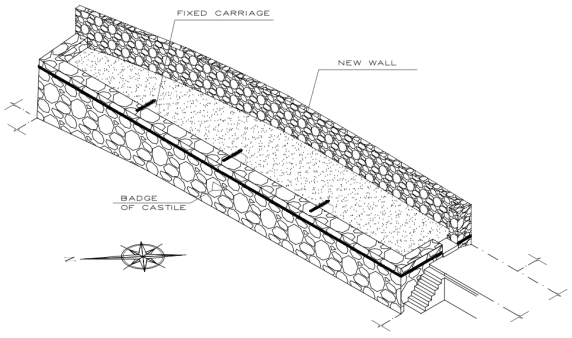

Figure 18. Current isometric representation of the fort *La Planchada* (2016).

in the continent of America, in which the art of warfare played an important role. Military operations conducted in those times were crucial to determine important aspects of the fort under study. Its location sought to face attacks either from pirates or from foreign armies belonging to conquering nations; but without neglecting indigenous tribe attacks. On the other side, technical aspects, such as an adequate escarpment to hinder maneuvers of the attackers, the geometry of its parapet, or the need for a moat and a glacis, were designed keeping in mind the poliorcetics or art of attacking and defending strongholds.

As for the fort *La Planchada*, its main function over time was to prevent an eventual landing of pirates and corsairs on the coast of the city. Concepción was the most important city in the country; however, it did not suffer attacks similar to the other cities. Therefore, the fortress had enough dissuasive power to intimidate the ships that prowled the city coastline.

The fort *La Planchada* never engaged in battle with any vessel; only a few warning shots to ships and some artillery skirmishes, before and after the proclamation of the independence of Chile, leading to minor damages to the fort.

Finally, the abandonment and negligence of the fort are due to four factors: the main concern with regards to the indigenous uprisings within the territory during the conquest period in Chile; the successive earthquakes and tsunamis experienced throughout its history; the move of the Concepción city to its current location (15 kilometers to the south of its original location); and the demolition of almost half its structure to build the railway line.

From a constructive perspective

The present study of the fort *La Planchada* identified the existence of three designs throughout its history: the barbette described by Frezier (1982); the Fort Castle described by Salcedo y Pineda and De Santa Maria (1763); and the fort today.

The barbette as described by Frezier in 1712 must have been the original fort as built by Jerónimo de Quiroga. No reparations orders nor earthquakes altering its design were found between the date of its opening and the visit by this French military engineer.

Its construction affirms that during that era, there were complex and amazing engineering procedures, which solved all types of difficulties, from the excavation for laying the foundations to the construction of each end of the parapets. The fact that the fort remains standing provides evidence of an efficient and admirable construction process.

Military engineers, who built fortifications in America, and specifically Jerónimo de Quiroga, did not follow rigid principles and methods; but indications coming from handbooks and supported by experience allowed the poliorcetics to be adapted to real conditions found onsite.

The second design and the first major transformation of the fort, emerged from the report of the Maestre de Campo Manuel Salcedo y Pineda and his Colonel Antonio de Santa Maria in 1763. They described it as a closed fortification with a lateral rake door and a countermure enclosing the inner main square; in military terms, a Castle Fort. The necessity for this type of construction was to fend off pirates and indigenous tribal attacks.

The third design, rather than another repair was a demolition, coinciding with the present-day construction. The interior rooms (storage and ammunition dump, and utilized as police headquarters and jail) were demolished to make room for the coastal railway. Today, the fortress has a main curtain facing the bay and a countermure that was probably erected on the original foundations of the demolished sections of the fort. The main wall of this building, despite its current modified state, corresponds to the original construction erected by Jerónimo de Quiroga.

As a corollary, it can be highlighted that this comprehensive literature review aims to contribute to the patrimonial rescue of military fort construction techniques, as used during the 17th century in America. Those techniques learned from the experience of ancient armies have been present until today, as the basis of military culture, in which learning from their fortifications have served as fundamentals principles for the art of warfare in the contemporary world.

Acknowledgement

This work was partially supported by the Chilean National Commission for Scientific and Technological Research under Grants No. 11140123/Fondecyt Iniciación and No. 1171108/Fondecyt Regular.

References

ALVIAL, A. 2003. *Fortificaciones españolas en la provincia de Concepción y su influencia en el desarrollo de las ciudades: estudio de casos*. Concepción, Ed. Universidad del Bío-Bío, 122 p.

ANTCZAK, M.M.; ANTCZAK, A. 2006. *Los Ídolos de las Islas Prometidas*. Caracas, Ed. Equinoccio, 630 p.

ARCOS, H.; PORCU, M. 2003. *Movimientos Sísmicos y Estructuras Murarías*. Madrid, Ed. Consorcio de Compensación de Seguros, 323 p.

BALLART, J.; TRESSERRAS, J. 2001. *Gestión del Patrimonio Cultural*. Barcelona, Ed. Ariel, 224 p.

BEUERMAN, T.E. 2009. *Inventory of Repairing and Strengthening Techniques for Masonry Arch Bridges.* Barcelona, Spain. M.Sc. thesis. Universitat Politècnica de Catalunya, 106 p.

BARROS, D. 2000. *Historia General de Chile, tomo I*. Santiago, Ed. Universitaria, 368 p.

BOSILJKOV, V.; MAIERHOFER, C.; KOEPP, C.; WÖSTMANN, J. 2010. Assessment of Structure through Non-Destructive Tests and Minor Destructive Tests Investigation: Case Study of the Church at Carthusian Monastery at Žiče (Slovenia). *International Journal of Architectural Heritage,* **4**(1):1-15. https://doi.org/10.1080/15583050902731031

BURGOS, L. 2014. *Caracterización de la estructura y de los procesos constructivos y rescate histórico del Fuerte La Planchada de Penco, Chile.* Concepción, Chile. B.Sc. Thesis. Universidad del Bío-Bío, 92 p.

CALDERINI, C. 2007. Use of Reinforced Concrete in Preservation of Historic Buildings: Conceptions and Misconceptions in the Early 20th Century. *International Journal of Architectural Heritage,* **2**(1):25-59. https://doi.org/10.1080/15583050701533521

CALDERÓN, J. 1996. *Las Fortificaciones Españolas en América y Filipinas*. Madrid, Ed. Mapfre, 768 p.

CAMPOS, F. 1980. *Historia de Concepción 1550-1970*. Santiago, Chile, Ed. Universitaria, 382 p.

CARTES, A. 2013. *Viajeros en tierras mapuches*. Tomé, Ed. Al Aire Libre, 117 p.

CARVALLO, V. 1875. *Descripción histórico-geográfica del Reino de Chile; Colección de Historiadores de Chile y Documentos relativos a la Historia Nacional, vol. IX*. Santiago, Ed. Imprenta del Ferrocarril, 488 p.

CERONI, F.; PECCE, M.; VOTO, S.; MANFREDI, G. 2009. Historical, Architectural, and Structural Assessment of the Bell Tower of Santa Maria del Carmine. *International Journal of Architectural Heritage*, **3**(3):169-196. https://doi.org/10.1080/15583050802347490

CHAVEZ, J.; BROCHE, J.; RECAREY, C.; SANCHEZ, F.; MAESTRE, M.; PEREZ, N. 2012. Técnicas de avanzada en el diagnóstico patológico de edificaciones: "El Templete" de la Habana Vieja. *Revista Ingeniería de Construcción,* **27**(2):19-33. https://doi.org/10.4067/S0718-50732012000200002

COX, G. 1998. *Historia de Concepción*. Santiago, Ed. Andújar, 308 p.

DE CEPEDA Y ANDRADA, A. 1669. *Epitoma de la fortificación moderna.* Brussels, Ed. F. Foppens, 390 p.

DE ROJAS, C. 1598. *Teoría y práctica de fortificación, conforme a las medidas y defensas de los tiempos*. Madrid, Ed. Luis Sánchez, 107 p.

D'URVILLE, D. 1842. *Voyage au Pole Sud et Dans L'Océanie Sur Les Corvettes L'Astrolabe et la Zélée*. Paris, Ed. Gide Editeur, 361 p.

D'WARTELET, J. 1863. *Diccionario militar: contiene las voces técnicas, términos, locuciones y modismos antiguos y modernos de los ejércitos de mar y tierra*. Madrid, Spain, Ed. Imprenta Luis Palacios, 767 p.

FERNÁNDEZ, S. 1979. *Memorias de los Sucesos de la Guerra de Chile, Jerónimo de Quiroga*. Santiago, Ed. Andrés Bello, 476 p.

FERNÁNDEZ, E.; WASHINGTON, Y. 2012. *Characterization of the response of quasi-periodic masonry: Geometrical investigation, homogenization and structural application.* Braga, Portugal. M.Sc. thesis. University of Minho, 99 p.

FREZIER, A. 1982. *Relación del viaje por el mar del sur.* Caracas, Biblioteca Ayacuch, 360 p.

GABRIEL, R.A.; METZ, K.S. 1991. *From Sumer to Rome: The Military capabilities of ancient armies*. Westport, Greenwood Press, 208 p.

GALINDO, J. 1996. *El conocimiento constructivo de los ingenieros militares del siglo XVIII.* Barcelona, Spain. Ph.D. thesis. Universitat Politècnica de Catalunya, 230 p.

GARCÍA, N.; MELI, R. 2008. On Structural Bases for Building the Mexican Convent Churches from the 16th Century. *International Journal of Architectural Heritage*, **1**(3):24-51. https://doi.org/10.1080/15583050701842344

GIL, I. 2011. Fundamentos constructivos de las fortificaciones bajomedievales en la provincia de Soria: fábrica de mapostería con vergaduras de ladrillo en el castillo de Arcos de Jalón. *In: Actas del VII Congreso Nacional de Historia de la Construcción*. Instituto Juan de Herrera, Madrid, p. 549-562.

GONZÁLEZ DE MEDINA, D. 1599. *Examen de Fortificación*. Madrid, Ed. Imprenta Lic. Várez de Castro, 228 p.

GUARDA, G. 1990. *Flandes Indiano*, *Las Fortificaciones del Reino de Chile 1541-1826*. Santiago, Ed. Universidad Católica de Chile, 425 p.

HERRERA, L.K.; LE BORGNE, S.; VIDELA, H.A. 2008. Modern Methods for Materials Characterization and Surface Analysis to Study the Effects of Biodeterioration and Weathering on Buildings of Cultural Heritage. *International Journal of Architectural Heritage*, **1**(3):74-91. https://doi.org/10.1080/15583050802149995

HONG, N.; KOH, H.; HONG, S.; BAE, B.; YOON, W. 2009. Toward a Balanced Heritage Management Plan for Old Stone Bridges Considering the Embedded Cultural Significance. *International Journal of Architectural Heritage*, **3**(3):195-211. https://doi.org/10.1080/15583050802344554

IBARRA, M.; BARRIENTOS, M. 2011. La Manzana de la Catedral en Santiago de Chile: Expansión y Contracción. *Historia,* **44**(1):91-129.

IDÁLIA, M.; DIAZ, T.; FARIA, P. 2012. Unstabilized Rammed Earth: Characterization of Material Collected from Old Constructions in South Portugal and Comparison to Normative Requirements. *International Journal of Architectural Heritage*, **5**(6):677-692.

INDIRLI, M.; APABLAZA, S. 2010. Heritage protection in Valparaiso (Chile): The "Mar Vasto" Project. *Revista Ingeniería de Construcción,* **25**(1):21-62. https://doi.org/10.4067/S0718-50732010000100002

LIGNOLA, G.P.; MANFREDI, G. 2011 Damage Assessment and Design of Structural Interventions for Monte di Pietà in Naples, Italy. *International Journal of Architectural Heritage*, **5**(6):647-676. https://doi.org/10.1080/15583058.2010.483565

MARTÍN, J.M. 2001. Ensayo de Análisis Comparativos de Técnicas, Materiales y Tipos Constructivos en las Fortificaciones Medievales del Zenete (Granada). *Miscelánea Medieval Murciana,* (25-26):183-229.

MELI, R.; SÁNCHEZ-RAMÍREZ, R. 2007. Criteria and Experiences on Structural Rehabilitation of Stone Masonry Buildings in Mexico City. *International Journal of Architectural Heritage*, **1**(1):3-28. https://doi.org/10.1080/15583050601123118

MUELLER, U.; KANAN, M.I.C. 2005. The microstructure of traditional Brazilian lime plaster – The Custom House of Florianopolis. *In*: Simpósio Brasileiro de Tecnologias de Argamassas; Internacional Symposium on Mortars Technology, VI, Florianópolis, Brazil, 2005. *Anais…* Florianópolis, **23**:736-745.

NIETO, V.; CHECA, F. 2000. *El Renacimiento: formación y crisis del modelo clásico*. Madrid, Ed. Istmo, 398 p.

OSSA, J. 2010. La Criollización de un Ejército Periférico, Chile, 1768-1810. *Historia,* **43**(2):413-448.

PALLADIO, A. 1998. *Los Cuatro Libros de la Arquitectura*. Madrid, Ed. Akal. S.A., 450 p.

PANIAGUA, D. 2007. La Arenga Militar, desde la perspectiva de la Tradición Polemológica Grecolatina. *Revista Interdisciplinar de Retórica e Historiografía,* **2**:1-25.

PECCHIONI, E.; GÓMEZ, M.; CAGNINI, A.; GALEOTTI, M.; FRATINI, F.; PORCINAI, S. 2014. Ancient and new repair mortars for conservation: Application to the case of San Leonardo Pulpit (Florence-Italy). *International Journal of Architectural Heritage*, **8**(4):556-580. https://doi.org/10.1080/15583058.2012.703758

PEDERSEN, A. 2002. *Managing Tourism at World Heritage Sites: a Practical Manual for World Heritage Site Managers*. Paris, France, UNESCO World Heritage Centre, 96 p.

PERES, R.M.; DE PAULA GASTAL, F.; GREVEN, H.A. 2011. Italian Heritage Building Technology in Pelotas. *International Journal of Architectural Heritage*, **5**(6):677-692. https://doi.org/10.1080/15583058.2010.487384

PÉREZ-GRACIA, V.; DI CAPUA, D.; CASELLES, O.; RIAL, F.; LORENZO, H.; GONZÁLEZ-DRIGO, R.; ARMESTO, J. 2011. Characterization of a Romanesque Bridge in Galicia (Spain). *International Journal of Architectural Heritage*, **5**(3):251-263. https://doi.org/10.1080/15583050903560249

RAE. 2001. *Diccionario de la Lengua Española, vigésima segunda edición*. Madrid, Spain, Ed. ERA, 2448 p.

RIVEIRO, B.; ARIAS, P.; ARMESTO, J.; ORDÓÑEZ, C. 2011. A Methodology for the Inventory of Historical Infrastructures: Documentation, Current State, and Influencing Factors. *International Journal of Architectural Heritage*, **5**(6):629-646. https://doi.org/10.1080/15583051003792880

ROSALES, D. 1878. *Historia General del Reyno de Chile, Flandes Indiano*. Valparaíso, Ed.Impr.del Mercurio, 676 p.

SAHADY, A.; BRAVO, J.; QUILODRÁN, C. 2011. Fuertes españoles en Chiloé: las huellas de la historia en medio del paisaje insular. *Revista INVI*, **73**(26):133-165. https://doi.org/10.4067/S0718-83582011000300005

SALCEDO Y PINEDA, M.; DE SANTA MARÍA, A.N. 1763. Estado de Fuertes y Plazas de la Frontera de Chile. *Catálogo del archivo de Claudio Gay*. Santiago, Ed. Archivo Nacional de Chile, **37**(17):149-181.

SCHNEIDER, O. 1950. *Libro de Oro de la Historia de Concepción*. Concepción, Ed. Litografía, 639 p.

SCHUEREMANS, L.; VAN BALEN, K.; BROSENS, K.; VAN GEMERT, D.; SMARS, P. 2006. Church of Saint-James at Leuven (B) – structural assessment and consolidation measures. *In: V Conference on Structural Analysis of Historical Constructions, Possibilities of numerical and experimental techniques*, New Delhi, p. 1729-1738.

SENA-CRUZ, J.; FERREIRA, R.M.; RAMOS, L.F.; FERNANDES, F.; MIRANDA, T.; CASTRO, F. 2013. Luiz Bandeira Bridge: Assessment of a Historical Reinforced Concrete Bridge. *International Journal of Architectural Heritage*, **7**(6):628-652. https://doi.org/10.1080/15583058.2012.654895

SILVA, A.S.; ADRIANO, P.; MAGALHAES, A.; PIRES, J.; CARVALHO, A.; CRUZ, A.J.; MIRAO, J.; CANDEIAS, A. 2010. Characterization of Historical Mortars from Alentejo's Religious Buildings. *International Journal of Architectural Heritage*, **4**(2):138-154. https://doi.org/10.1080/15583050903046322

SOLÍS, M.; DOMÍNGUEZ, J.; PÉREZ, L. 2012. Structural Analysis of La Giralda's 16th-Century Sculpture/Weather Vane. *International Journal of Architectural Heritage*, **6**(2):147-171. https://doi.org/10.1080/15583058.2010.518660

STRENCHOCK, L. 2009. *Research on the restoration of heritage structures: Portland cement and concrete repair applications and repercussions.* Barcelona, Spain. M.Sc. thesis. Universitat Politècnica de Catalunya, 74 p.

TORREJÓN, F.; KING, C.; VIRANO, P. 2002. El Auge de la Ciudad de Concepción en Penco, las Variables Geohistóricas del Siglo XVII. *Urbano,* **5**(6):73-79.

TRIBULOVÁ, T.; KOTLIK, P. 2015. Material studies within the scope of pre-project preparations for restoration of a significant Czech country church. *International Journal of Architectural Heritage*, **9**(4):352-366. https://doi.org/10.1080/15583058.2013.787469

VIDAL, F. 1938. Índice del Archivo Hidrográfico *"Vidal Gormaz" – Archivo Nacional de Chile*. Santiago, Ed. Imprenta Universitaria, 37 p.

WAGNER, A. 2010. *Fortificaciones históricas de Valdivia: 2010, año del Bicentenario*. Santiago, Ed. Universidad San Sebastián, 315 p.

Submetido: 17/02/2017
Aceito: 01/11/2017