

Evolution of the Structural Systems of Vernacular Buildings in Santorini in Southern Greece

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Abstract

Santorini is an island of the South Aegean Sea in the Cyclades, in southern Greece. It is known and admired for the natural beauty of its volcanic landscape its unique rock-hewn settlements, its rare natural wealth. Its importance also focuses on its rich history, while after being under the Venetian and Ottoman rule for many centuries it inherited a rare religious, social and cultural background.

The paper focuses on Santorini's rare building structures and structural elements, created from the local volcanic materials and the wise ways these were used to produce high standard constructions and unique architecture. The applied methodology is based on the division of the time period between the 13th c, until the beginning of the 20th c and in three more specified periods which are the Venetian period (1204-1536), the Ottoman period, from 1536 -the year that the Aegean is conquered by the Turks- (1537-1774) and the Modern Greek period, after the signing of Treaty of Kucuk Kainarca in 1774 (1775-1956).

The methodology in this paper also involves the location and analysis of the structural elements (foundations, masonry walls, vaults etc) in a number of dated buildings¹ deriving from each aforementioned period. The comparative results for each structural element, offer a panorama of Santorini's history and evolution of its constructional methods, invented and used during the studied time period.

Keywords: Santorini, theran earth, Aegean, volcanic materials, Cyclades, Venetocracy.

Objective, aim and methodology

Santorini is an island located in southern Greece, Europe. It belongs to the complex of Cyclades in the Aegean Sea (Fig.1). Apart from its natural beauty, Santorini is also known for the fierce activity of an underwater volcanic core, set in the middle of its semicircular formation. Its vast explosions and earthquakes have been accused for the decline of important civilizations, such as the Minoan (1613 B.C.)², as well as for other severe destructions of manmade presence. Its explosions are also responsible for the creation of a very unique natural environment. For many centuries the island has been covered by a thick layer of ash and lava excluding any natural water source³ from its surface and providing extremely poor vegetation. One may think that an environment without water, timber and clay is inappropriate to create a friendly built environment. Nevertheless, the volcanic materials⁴, processed by the local craftsman's wisdom have provided the science of construction with a rare type of building

¹ Ritzouli, K (2016) Η εξέλιξη της αρχιτεκτονικής και της οικοδομικής τέχνης στη Σαντορίνη από τη Βενετοκρατία μέχρι τον σεισμό του 1956, Phd .Thessaloniki: Aristotle University of Thessaloniki

² Vougioukalakis G (2015) Η δημιουργία της Θηρασίας και η μορφολογία της την Ύστερη Εποχή του Χαλκού In: K. Palyvou and I. Tzachili, ed. ΘΗΡΑΣΙΑ Ι Μια διαχρονική διαδρομή, Athens: Τα Πράγματα, pp. 20-32.

³ Bitis, I (2013) Water supply methods in Ancient Thera: the case of the sanctuary of Apollo Karneios. IWA Publishing 2013 Water Science & Technology: Water Supply, 13.3.2013.

⁴ Koumanoudis, I N (1960) Η λαϊκή εκκλησιαστική αρχιτεκτονική της Θήρας, Phd. Athens: National Technical University of Athens, pp. 3-4

technology. Materials such as black and red volcanic stones, pozzolanic earth⁵, lime, river sand, sea sand and seawater or rainwater, create Santorini's rare structures and interesting architectural complexes.

From the Venetian era onwards, Santorini displays an impressive stock of both monumental and vernacular buildings, fact that reveals that the constructional diversity was not an obstacle to their realization. The key issue for the successful local craftsmanship was basically the use of "theran earth"⁶, a pozzolanic natural cement with hydraulic properties. The produced mortars became the binder material for the construction of vaulted horizontal carriers and the waterproofing material for the final buildings' coatings.

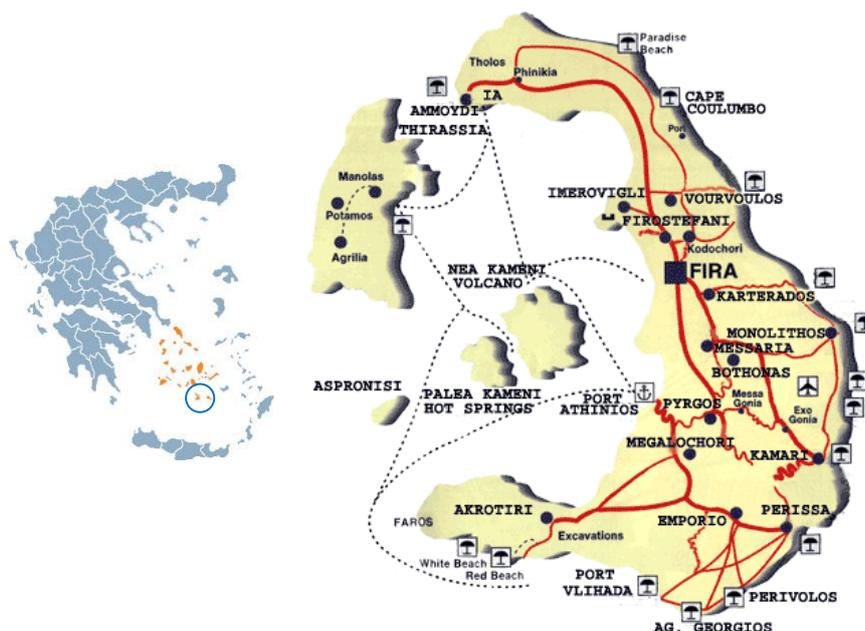


Fig. 1. Left: Map of Greece. Right: Map of Santorini.

Source: <http://www.visit-santorini.com/site/maps.htm>, accessed 12-04-2017

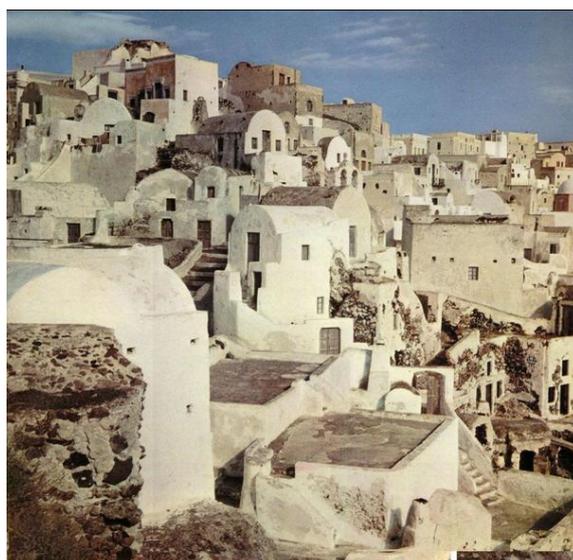


Fig. 2. Typical dense architectural formations in Santorini.

Source: L. Papadopoulos collection

⁵ Reizidou, E (2015) Τα ορυχεία θηραϊκής γης στη Νότια Θηρασιά. In: K. Palyvou and I. Tzachili, ed. ΘΗΡΑΣΙΑ Ι Μια διαχρονική διαδρομή, Athens: Τα Πράγματα, pp. 218-228

⁶ The word "theran" derives from "Thera" which is the name of Santorini during ancient times.

In order to achieve an overview of the evolution of Santorini's construction systems, a number of dated buildings have been analyzed down to their individual structural elements, such as: foundations, masonry walls, horizontal carriers, floors, tiered pathways, stairways and openings. The proposed time period from which the objectives have been selected is set between two important milestones: the year 1207, during which the Venetian family of Barozzi becomes the feudal lords of the island after the 4th Crusade. The second milestone is the earthquake of 1956 which destroyed most of the existing building stock. 1956 has also set the turning point in Santorini's constructional history while after that year the technology of concrete is introduced as the exclusive substitute for all previous traditional building technology. The methodology applied also involves the division of the aforementioned time period in three more specific ones: The first one is the Venetian, from 1207 until 1536. It is succeeded by the Ottoman period from 1537 when the island is set under the Ottoman rule, until 1774. The third period initiates with the Treaty of Kucuk Kainarca which signifies the birth of the Modern Greek State and ends with the earthquake of 1956.

The aim of the paper is the study and comparison of each structural category, in order to track and document a possible evolution on each structural element and consequently on the evolution of the island's structural systems.



Fig. 3. The built environment of the settlement Oia, in the island of Santorini

Source: www.pronews.gr, accessed 04-03-2017

Venetian era: Buildings and Structural elements

The interesting history of Santorini after the Byzantine era and the diverse socio-political and religious activities that took place in its grounds, endowed the island with a unique architecture. The Venetian era (13th c-16th c) bonds Santorini to the Duchy of Naxos, or Duchy of the Archipelago. This era is characterized by the effort of the inhabitants to create settlements and provide themselves protection from the pirates, along with the basic needs, such as water and food. Being invisible in rupestrian habitations was the choice of the poor, whereas the gentry could afford to live in conspicuous castles, difficult to reach and to conquer⁷. The Venetians left an innovative architectural legacy and brought many new building techniques, most of them strictly adopted to the island's materials and conditions.

The dated buildings of the first period (1204-1536) in Santorini are the five castles: Scaros, Emporio, Pyrgos, Akrotiri and Ag. Nikolaos. Inside these, the residences, churches and towers of the Venetian era (Fig. 3) are still preserved, some of them in good condition, some others in ruins.

⁷ Palyvou, C. (2015) Modes of habitation in Thera and Therasia: a history of display and concealment. In: K. Palyvou and I. Tzachili, ed. *ΘΗΡΑΣΙΑ Ι Μια διαχρονική διαδρομή*, Athens: Τα Πράγματα, pp. 124-141.



Fig. 4. the castle of Ag. Nikolaos (Oia)



Fig. 5. The tower of the Venetian castle of Akrotiri.

Source: Argie Kakissis collection



Fig. 6. The Venetian castle of Emporio

Source: www.kastra.eu

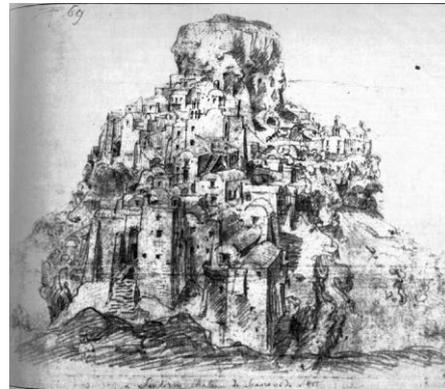


Fig. 7. Skaros the catholic capital of Santorini.

Source: Thomas Hope (1769-1831) collection. Images from Greece of the 18th c Athens 1985, Benaki Collection.

Foundations

It seems that, during the Venetian period, the position and typology of the demanding, innovative buildings were executed according to a basic plan, on specific chosen sites. The essential preparation of the ground is visible on the preserved sites. Works such as the leveling of the rocks and the construction of retaining walls for further foundation reinforcement is obvious until today.

In the case of Ag. Nikolaos tower in Oia⁸ (Fig. 9), the foundation rock is hewn, leveled and extended around its perimeter with dense masonry, which increases the bearing surface by 0,50m around the edges. A uniform vertical front of foundation and masonry wall on the cliff completes the construction.

The tower of Akrotiri (Fig. 8) also rests on an, extended around its perimeter, horizontal level. The masonry foundation fronts are not as carefully built as the superstructure.

⁸ Ritzouli, K (2016) Η εξέλιξη της αρχιτεκτονικής και της οικοδομικής τέχνης στη Σαντορίνη από τη Βενετοκρατία μέχρι τον σεισμό του 1956, Phd .Thessaloniki: Aristotle University of Thessaloniki, pp. 148



Fig. 8. The tower of Akrotiri after the earthquake of 1956.

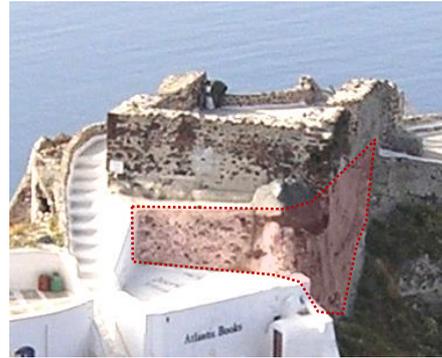


Fig. 9. The tower of Ag. Nikolaos after the earthquake of 1956.

Masonry walls

During this time period, four types of masonry walls are observed: (a) masonry walls in monumental constructions (Fig.10), (b) walls of buildings inside the castles, which is the most common type (Fig.11), (c) flank walls called ‘skarpes’ (Fig.12) and (d) masonry that covers and supports the interiors of the rock – hewn structures (Fig.13).

The masonry walls in monumental buildings (a) have particularly elaborate edges with cornerstones and are built with densely arranged stones. This constructional method is achieved by the simultaneous construction of both sides of the wall by two builders and filling the interior less regularly, with stones and pozzolanitic mortar. This type of masonry wall is 1,25 - 1,40m thick.

The same technique is observed in the common case of masonry walls inside the castles (b). These walls reach 0,65 - 1,50m thickness. Usually the outer side appears more elaborate than the inside. The cornerstones are well worked, but not as much as those of type (a).

The (c) type of wall is a prominent, retaining wall type. The low reinforced masonry with its smoothly decreasing superstructure, receives both the upper loads and the strong horizontal forces. These walls are located at the perimeter of all the Venetian castles of Santorini, as in the external flanks of Akrotiri, in Skaros (Fig. 7), in the north exterior walls of Pyrgos and Emporeio. “Skarpes” are also located in small defense type buildings, close to the castles. In no other period is this type to be found.

In rock-hewn structures (d), masonry walls often cover the inner surfaces of the cave. The choice of materials is the same as the above. Red, light, porous stones cover the vaults, while the black ones cover the vertical surfaces (Fig.13).



Fig. 10. Type (a)
The tower of Akrotiri
Source: author



Fig. 11. Type (b)
Typical house in the
castle of Pyrgos
Source: author



Fig. 11. Type (c)
“Skarpes” in
Akrotiri.
Source: Argy
Kakassis collection.



Fig. 12. Type (d)
Differentiation in the
use of materials
Source: author

Horizontal carrier

Vaults

The lack of wood led to the invention of resistant horizontal carriers: the “theran” vaults (Fig.14, 15, 16). These, in combination with the high strength pozzolanic mortars, adequately supported all structures over the centuries. The construction of the traditional “theran” vault is achieved by pouring stones and pozzolanic mortars upon a molding system, which is removed after the construction hardens. The top of the construction is then filled with layers of materials, such as pumice, stones, raw and fine mortars, in order to create flooring interior surfaces or exterior insulated surfaces. The usual form for the castles’ units is the semi-circular barrel vault.

During the first period, there is no evidence of groin vaults in Santorini. The groin vault is a pure western architectural element, which, if ever built in Santorini during the studied period is lost in the ruins of Skaros⁹.

Domes

The main characteristic of the island’s square- plan temples of the first period is their domes. The oldest ones are low and erected on octagonal drums, pierced by pointed openings. Unlike the case of the ducal palace in Naxos¹⁰, it seems that, in Santorini, the western idea of a religious space was realized with byzantine and theran building expertise.

Floors, tiered pathways and stairways

Interior spaces

During the Venetian period, the traditional sand-and-theran-earth based mortars are the main flooring materials inside the traditional residences, because of their moisture resistance properties. For more elaborate constructions, such as churches, the most frequent flooring material is the “malta” stone, a light yellow tinted lime stone (Fig. 40).

Exteriors

The public areas in the Venetian castles of Santorini are paved with stones with the technique of “plakoto”¹¹ (Fig. 19), a highly resistant construction. “Plakoto” is used in public spaces and streets and as flooring material in small pre – industrial buildings such as wineries, during the second and third period.

⁹ The first capital of the Venetians on the island and then capital of the catholics, until its complete catastrophe after some severe earthquakes during the 19th c.

¹⁰ Vavatsioulas, O (2007) Το Κάστρο της Νάξου, Phd. Athens: National Technical University of Athens.

¹¹ Palyvou, K, Ritzouli, K. (2014) Αρχιτεκτονικές επεμβάσεις μικρής κλίμακας σε παραδοσιακούς οικισμούς της Σαντορίνης: Το παράδειγμα του Πύργου Καλλίστης, Santorini: ed. Τυποκυκλαδική Α.Ε. pp. 25



Fig. 14. The entrance of the Emporio castle.



Fig. 15. A typical vault inside the castle of Pyrgos.
Source: Stella Ntakovanou, architect



Fig. 16. Pyrgos castle. The vaulting system forms the building's horizontal carrier and type (b) masonry walls.
Source: Stella Ntakovanou, architect



Fig. 17. The interior of Theotokaki's dome.

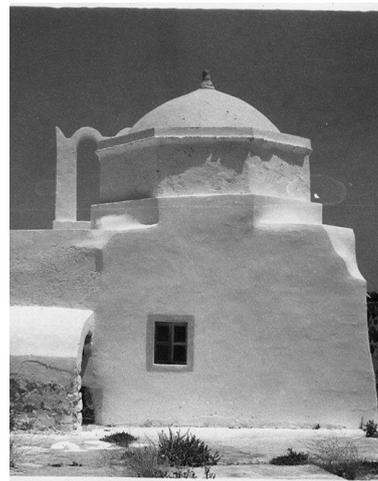


Fig. 18. Dome of the church of Theotokaki in the castle of Pyrgos
Source: S. Lada 1968



Fig. 19. A path inside a castle. The traditional technique is called “plakoto”.



Fig. 20. The tiered pathway at the entrance of Akrotiri castle.

Openings

Lintels and door / window frames

In all periods, the materials used for lintels and door or window frames are the red porous stones or the marble. The durability of these materials, combined with the sophisticated traditional construction techniques has produced high performance structures.

The red volcanic porous stone creates semi-circular arched door frames (Fig. 21), especially inside the standardized castle’s external openings. Red stone is also used as a monolithic horizontal lintel with or without side corbels. (Fig.22, 24).

Marble is also used as lintel for the temples’ door frames, decorated with an etched circled cross.



Fig. 21. Typical frame of external door in Emporio castle.



Fig. 3. Door and window frames made of red volcanic stone.



Fig. 23. Typical cross on the marble lintel of a church.



Fig. 24. External door in Pyrgos castle.

Ottoman era: Buildings and Structural elements

Venetocracy is succeeded by the Ottoman era (16thc-18thc), a turbulent period, characterized by the outbreaks of the Venetian – Turkish wars. Rupestrian habitation and other defensive positions reach their peak on the island. During the 15th c. and mid-16thc. Kapudan Pasha,

Heiredin Barbarossa wreaks havoc on the populations of the islands and coastal areas¹². The transition from Venetian to Turkish sovereignty consolidates in 1566¹³. That year, the Ottoman Sultan Selim II grants the exploitation of the most important islands of the Cyclades to the Portuguese¹⁴ Joseph Nazis (1520 approximately -1579) under the title of Duke, with the obligation to pay the Gate an agreed amount of money. The fate of Santorini connects with its new dominant, a great merchant and inhabitant of Constantinople, who never settles in the Aegean. For the tax collection, Nazis uses old Latin families in the administration.

From the middle of the 16th c., the Aegean, acquires a single administration and is transformed into an "Ottoman lake", with the unprecedented character of a single island area, after centuries of fragmentation¹⁵.

The difficulty in finding dated buildings during the Ottoman period (1537-1774) reflects the continuous and uninterrupted habitation of the areas created during the 16th c until today. It also reflects the absence of monumental buildings. It seems that the "richest" concentration of important buildings was located in the castle of Skaros¹⁶ (Fig. 7), the catholic capital of Santorini, which, after the volcanic explosion of 1650, began to depopulate until its desolation in 1800.

However, a unique dated sample of a residence near Skaros, is preserved until today, reflecting a possible type of architecture that is now lost in the ruins of Skaros: Megaro Ghisi, (Fig. 25, 26, 29) built in 1700.

The churches of the second period, both orthodox and catholic, present several innovations, in morphology and typology and size. Any other new types of buildings have not been located.

¹² Ιστορία του Ελληνικού Έθνους (Ι.τ.Ε.Ε.) vol. Ι', 1974, pp. 80

¹³ Ιστορία του Ελληνικού Έθνους (Ι.τ.Ε.Ε.) vol. Ι', 1974, pp. 306

¹⁴ Vasilopoulos, N (2015) Λατινοκρατία στην Άνδρο: Κάστρα, Πύργοι, εκκλησίες και φέουδα, 2nd ed. Andros: (s.n.) pp.34

¹⁵ Dimitropoulos, D (2004) Μαρτυρίες για τον πληθυσμό των νησιών του Αιγαίου 15^{ος} – αρχές 19^{ου} αι. τετράδια εργασίας 27, Κέντρο Νεοελληνικών Ερευνών, Athens: National Institute of Research pp. 34

¹⁶ Παλυνου, Κ. (2006) Σκάρως, η πρωτεύουσα της ενετοκρατούμενης Θήρας. Ιστορία, παρόν και μέλλον. In: G. Karadedos (ed.), ΔΩΡΟΝ. Τιμητικός Τόμος στον Καθηγητή Νίκο Νικονάνο. Thessaloniki: 10th E.B.A. – Sector Δ' Department of School of Architecture of the Polytechnic School A.U.Th., pp. 615-626



Fig. 4. Megaro Ghisi 1700.
Internal courtyard.



Fig. 26. Megaro Ghisi
1700.



Fig. 27. Church of Ag. Georgios
in Megalochori 1600.

Foundations

During the Ottoman period, the basic construction methods remain the same. The ruins in Scaros, show that foundations follow the ground's geomorphology and large rocks are often incorporated in them. The church of "Ag. Stylianos o Fragos", in Fira (1757) is an interesting example of this period: The preparation of the ground is completed with the construction of two successive horizontal pedestals and parallel works for retaining the vertical surfaces (Fig. 28).

Masonry walls

The thicknesses of the walls during the Ottoman period are about 0,70m and not higher than 6,50m. They are built in the same way as in the common (b) type of the Venetian period (Fig. 11), but only found in more luxurious constructions, such as temples.

Horizontal carriers

Cylindrical vaults and arches

During the second period, barrel vaults and semicircular arches, pointed or not, are often found in vaulted basilicas and in Megaro Ghisi (1700). It seems, however, that the primary role in luxurious constructions is played by groin vaults, while barrel vaults serve mainly ancillary areas.

Groin vaults

Groin vaults cover the main areas of large scale temples and mansions, such as Megaro Ghisi (Fig. 29). The construction technique imitates the morphological western examples, implemented by the same local traditional technique of vaulting.

Other carriers

The use of timber carrier is only found and preserved until today, in extremely rare cases, such as the case of Megaro Ghisi (1700) (Fig. 30), in the monastic catholic complex of the Lazarists (Fig. 51) and inside the church of "Sylifthisa"¹⁷, buildings with direct influences from external western resources

¹⁷ Ritzouli, K (2016) Η εξέλιξη της αρχιτεκτονικής και της οικοδομικής τέχνης στη Σαντορίνη από τη Βενετοκρατία μέχρι τον σεισμό του 1956, Phd .Thessaloniki: Aristotle University of Thessaloniki, pp. 356

in architecture. It is thought that the architectural legacy of Scaros, today left as ruins, might have given us more feedback on this technology.



Fig. 28. Ag. Stylianos o Fragos 1757. Successive horizontal pedestals on the cliff.



Fig. 29. The groin vault of Megaro Ghisi's internal courtyard.



Fig. 30. Megaro Ghisi. The timber horizontal carrier.

Domes

During the second period, the use of domes is extensive on the religious buildings and adorns both vaulted basilicas and square-in-plan typologies. Variations on the drum are located on their interior (octagonal or rarely cylindrical) and at its decoration (small scale columns and arches) (Fig. 36, 37). Their diameters do not exceed 4.00m - 4.50m. Dated examples show that both lanterns and the anchored stones on the main domes (Fig. 34) appear around mid-18thc and are observed throughout the third period.



Fig. 31. Church of Ag. Nikolaos in Pyrgos castle (1653).



Fig. 32. Church of Ag. Aikaterini in Oia (1600).



Fig. 33. The dome of the church of Ag. Ioannis in Fira (17th c)



Fig. 34. Church of Ag. Alexios in Fira. Decoration with lantern and anchored stones.



Fig. 35. Church of Ag. Nikolaos in Pyrgos castle (1653).



Fig. 36. Church of Ag. Aikaterini in Oia (1600).



Fig. 37. Church of Panayia Messiani in Emporio castle. (17th c)



Fig. 38. Church of Zoodochos Pigi, in Oia.

Floors, tiered pathways and stairways

Interior spaces

During the second period, the theran earth - based mortars are the plain constructions' usual flooring material, in residences or humble churches. Marble plates or "malta" stones (Fig. 39, 40), placed in horizontal, and/ or diagonal rows, with or without a frame pattern are found in large scale churches. Traces of the old "malta" stone flooring (Fig. 40), (plates of 0,50X050m) are found in the ground floor of Megaro Ghisi (1700).

The use of pebble flooring called "votsaloto" (Fig. 41) is usually found at temple courtyards and at the main entrances of mansions.

Openings

Most of the door frame construction methods are the same as the previous centuries. However, an etched marble icon above the lintel is often found at the central doorframes of the temples, after 1600 (Fig. 42).



Fig. 39. Marble flooring. Internal courtyard in Megaro Ghisi.



Fig. 40. Malta stones as flooring material.

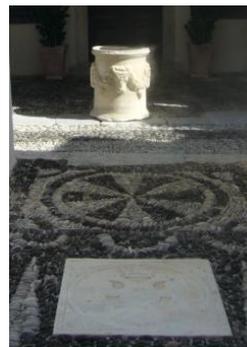


Fig. 41. Pebble stone floor in Panayia Messiani. Castle of Emporio.



Fig. 42. Semi-circular arched door in Pyrgos. 1660 church of Eisodia Theotokou.

Modern Greek period

The idea of the Modern Greek State revival emerges after the signing of the Treaty of Kucuk Kaynarca in 1774. During this time period, there is a continuous development in all areas of the island, which is vividly expressed through the construction of imposing mansions (Fig. 43, 44) and churches (Fig. 46, 47).

The luxurious residences are the result of local innovations and experimentations, which presuppose a growing and wealthy society, tuned with its contemporary European prosperous world. The temples are constructed larger and more impressive. At the same time, the architecture of the island is enriched by the Catholic monastic complexes of Fira, Santorini's new capital. The three monasteries, "imported" from the West through the monastic movements, left a surprisingly bright architectural heritage (Fig. 45).

The earthquake of 1956 is remembered as a dark spot on the island's history. During that day a great number of historic buildings collapsed and many more were brought down by the army, so as to provide a safer environment for the survivors. That year also signifies the point when new and different building materials, such as concrete, are imported in the island by the army, and change the island's building philosophy forever.



Fig. 43. The Markezini mansion in Messaria. 19th c. A neoclassical example.

Source: Archive of Santorini's Municipality Technical Office.



Fig. 44. 19thc. Mansion in Oia. An example of eclecticism.



Fig. 45. The monastery of the Lazarists.
Source: Kokkalakis, I. (2012) pp. 125.

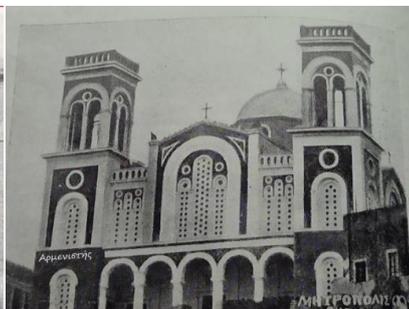


Fig. 46. Church of Panayia of Bellonia before its collapse.
Source: Argyros G. collection.



Fig. 47. Church of Panayia Platsani in Oia.
Source:
Koumanoudis, I.
1960, Fig. 285.

Foundations

During the Modern Greek period, the construction sites are mainly the new urban extensions of the existing settlements (Oia, Messaria etc), characterized by a much smoother relief and more regular urban plans. Information about the construction of the church of Timios Stavros in Perissa, built in 1837 (Fig. 48), refer to the construction of its foundations by the formation of a basin of 0,60m depth, which was filled with a pozzolanic mortar and volcanic stones, upon which the church was founded¹⁸.

¹⁸ Koumanoudis, I N (1960) Η λαϊκή εκκλησιαστική αρχιτεκτονική της Θήρας, Phd. Athens: National Technical University of Athens, pp. 53

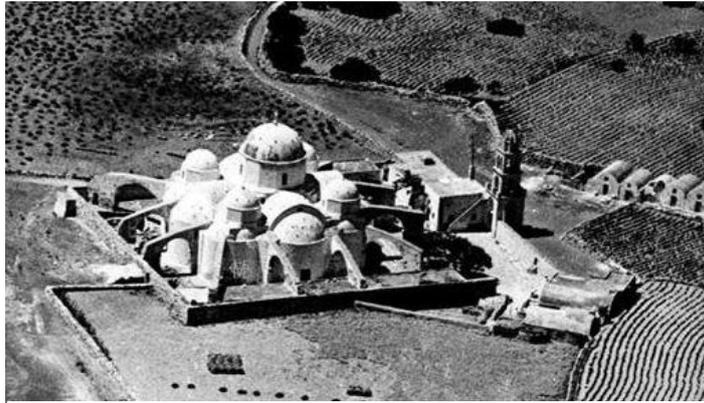


Fig. 48. The church of Timios Stavros in Perissa built in 1837.
The picture was taken in 1941
Source : Internet archive «Το Κέρας της Αμάλθειας», in
www.facebook.com (08-06-2016)

The foundations during the third period are in general shallow and constructed with empirical methods, without particular geological investigations. The resistance of buildings in earthquake intensity is also calculated empirically.

Masonry walls

During the Modern Greek period the same (b) common masonry type (Fig. 11) is used for the most important constructions, such as temples, mansions and industrial installations. The outer walls are usually about 0,80m thick and the inner walls 0,50m thick. Their construction quality is not as reinforced as the previous years¹⁹. The cornerstones are not well-worked the masonry stones are not densely placed. However, during this last period, the use of metal reinforcing elements inside the masonries in very few cases is worth mentioning.



Fig. 49. Mansion in Messaria (19th c). The vaulting system forms “skafes” in the interior.



Fig. 50. A painted ceiling on the “skafe” of Markezini mansion in Messaria. (late 19th c)



Fig. 51. Monastery of the Lazarists. A rare example of wooden horizontal carrier.

Horizontal carrier

During the third period semicircular barrel vaults, groin vaults, and even more complex forms, “skafes” (Fig. 9), are being located.

¹⁹ Ritzouli, K (2016) Η εξέλιξη της αρχιτεκτονικής και της οικοδομικής τέχνης στη Σαντορίνη από τη Βενετοκρατία μέχρι τον σεισμό του 1956, Phd .Thessaloniki: Aristotle University of Thessaloniki, pp.352.

Cylindrical vaults and arches

During the third period, “islamic type” arches and semicircular vaults and arches coexist in many constructions (Fig. 52), while the central arches are often decorated with oriental architectural elements. Semicircular arcades are only found at the porticoes of the monastic structures of the Lazarists (Fig. 45) and the Sisters of Mercy and at the mansions’ lowest levels (Fig. 43).

Groin vaults

Groin vaults shelter the porticoes around the courtyards of the aforementioned catholic monastic complexes (Fig. 53) and those of the mansions’ primary, and later on, secondary spaces. They are also very popular in churches.

The ceiling technique of “Skafes”

“Skafe” is an architectural and structural element, constructed by the same vaulting methods. It is used as the main mansions’ ceiling from 1860’s and on²⁰, replacing groin vaults. During the late 1880’s and early 1890’s “skafes” cover most of the mansions’ main rooms. At that time, unique ceiling paintings are created on the flat surfaces, offered by this imposing structural element (Fig. 49, 50).

Domes

During the third period, the temples are numerous and magnificent. The average diameter of the domes increases and exceeds 5m. In 1837 the church of Timios Stavros in Perissa bares the largest dome on the island with a diameter of 8.70 m. (Fig. 48)



Fig. 52. Different forms of apses coexist in the catholic Duomo in Fira.



Fig. 53. The monastic complex of the Sisters of Mercy.



Fig. 54. The dome of the old church of Panayia Platsani in Oia.
Source: Koumanoudis, I. 1960.

The domes’ drums are octagonal and have similar decoration with the latter ones. They are also adorned with horizontal cornices. Lanterns and smaller domes around the main dome are popular (Fig. 54). The type of five - domed churches appears during the late 19th c, while the rare use of clay tiles is found at the church of Ag. Charalambos in Exo Gonia. In two cases there have been located fusiform (umbrella) shaped domes (Fig. 54).

*Floors, tiered pathways and stairways**Interior spaces*

During the third period, the floors of the temples are primarily coated with white marble and, less frequently, by combining two colors of marbles, placed in horizontal or diagonal patterns. The use of “malta” stone plates is limited to the side aisles. During the decade 1920-1930 it is common to see the replacement of “malta” stones with concrete tiles.

The most important innovation of this period is the use of wood for the mansions’ flooring. It is constructed by riveted long planks about 0,12m width, brought by Santorini’s ships from all over the Mediterranean and the Black Sea.

²⁰ Ritzouli, K (2016) Η εξέλιξη της αρχιτεκτονικής και της οικοδομικής τέχνης στη Σαντορίνη από τη Βενετοκρατία μέχρι τον σεισμό του 1956, Phd .Thessaloniki: Aristotle University of Thessaloniki, pp. 335.



Fig. 55. Timber flooring in Markezini mansion (19th c.)



Fig. 56. Interior of the Lazarists' Monastery. Concrete tiles.

Exteriors

The technique of "plakoto" is still used on the public streets, inside the industrial buildings and as the tread for all tiered pathways. The riser is always a row of long volcanic stones or marbles, which restrains the horizontal pressure.

Pebble flooring is often located outside the front entrances of the mansions.

Marble flooring is observed at the courtyard of the monastery of the Sisters of Mercy and at the main public street of Oia.

Openings

Lintels and door / window frames

The third period shows some important examples of marble door framing, sometimes adorned with pediments or other types of decoration. The owners of the mansions use its surface to etch their initials and the date of the building's erection.

However, during this same period the monolithic lintels are often replaced by a less adequate system, constructed by stones placed in a row and bonded with theran mortars. These lintels created vulnerable parts in the structures and associate this period with a general decline in the quality of building construction after 1860.



Fig. 57. Different types of external doors and door frames

Conclusions

Interesting results come up with the comparison of each structural element during the three aforementioned periods and are analyzed below by category:

Foundations

The Venetians built on very particular sites with difficult accessibility, fact that increased the construction requirements. However, taking advantage of the rigid rocks, and incorporating them in the structure, they produced constructions of high efficacy. Very often, the ground was leveled and extended around its perimeter with dense masonry, increasing the bearing surface.

The same techniques were used during the second period: Preserved examples show that the ground was often leveled by successive horizontal pedestals and parallel works for retaining the vertical surfaces.

The third period buildings are characterized by very shallow foundations. It seems that, although there is a very intense creativity in terms of architecture (larger scale structures, innovative plans), the engineering part is empirical and the older tested construction methods have been abandoned.

Masonry walls

The Venetian period presents a variety of masonry walls, used in different types of buildings. The most efficient are used for the towers inside the castles (type a, Fig. 9) and for the castles' flank walls (type c, Fig. 11). These two types are not to find in later centuries. The other types continue to be built during all the succeeding time periods. The masonry technology used during the Modern Greek period presents signs of regression. However, the use of metal reinforcement elements is noted here as important.

Horizontal carriers

The constructions during all the studied eras use the same vaulting method, the "theran vaults" as their unique horizontal carriers. They are formed as barrel vaults during the Venetian period and as groin vaults for the main spaces for the ottoman period. From 1860's onwards, "skafes" cover most of the mansions' rooms, while groin and barrel vaults cover the secondary spaces.

Timber horizontal carriers are very rare, but still found in the areas of the catholic monasteries.

Domes

The main characteristic of the island's square-plan temples of the first period is their low domes, built on octagonal drums and pierced by pointed openings. The succeeding time period is characterized by wider (4.00m - 4.50m) diameters and taller domes, still based on octagonal or rarely cylindrical drums. They are often decorated with lanterns and anchored stones. The third period is represented by the dome of Timios Stavros in Perissa with a diameter of 8.70 m. Some rare forms of domes appear, such as the fusiform (umbrella) shaped dome and the clay tiled dome.

Floors, tiered pathways and stairways

During all the aforementioned centuries, the traditional sand-and-theran-earth based mortars are the main flooring materials inside the residences. A more expensive material, the "malta" stone is used during the Ottoman era for the churches' interiors. Later on, they are only used for the ancillary areas, while marble is preferred for the main spaces of the churches, and timber for the important rooms of the mansions.

As for the external pathways, the technique of "plakoto", is used until today. The pebble flooring is still always preferred for the courtyard of more important buildings.

Openings

Lintels and door / window frames

The materials used for door or window frames are the red porous stones, or the marble as far as the first and second time periods are concerned. Black volcanic stones binded with theran mortars are found as frames during the third period, creating vulnerable parts on the constructions.

As an epilogue

Santorini's built environment remains unique until today. It is important to realize, that the island's strange and rare natural wealth has always been the raw material in every construction for centuries, no matter its importance or size. The special properties of the materials, in combination with the craftsmen's sensitivity and sense of the environmental wholeness, converted the volcanic hostile earth into a model for harmonizing the environment with the constructed, organized space. For this

reason, it seems that building structures have not changed, throughout the studied period, but have only evolved.

On the other hand, the import of cement and concrete on the island has utterly changed the traditions in building, creating new technologies and new ethics on architecture and environmental management. It is necessary to recognize the importance of the traditional craftsmanship that created this rare built environment and pass it on to the next generations, as a live intangible heritage and a dynamic tool to protect its monuments.

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