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Erudite vaults by anonymous builders: The vaulted houses of Fuzeta (Portugal)

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ABSTRACT: The fishing village of Fuzeta, in southern Portugal, provides a remarkable and yet unique example of Mediterranean vernacular architecture. Although most of the buildings in the historical centre were built between the 19th and the first half of the 20th century, the underlying urbanism dates to the 17th century with the first fishermen settlements located on the seafront. The homogeneous architecture is particularly relevant because of the pervasive use of a typology of houses with terraces on brick vaults with different shapes and geometries – lowered barrel, sail and cloister – still preserved today. This paper characterizes, analyzes and compares the types of brick vaulted houses in Fuzeta. The conducted research indicates that these anonymous constructions were nourished by an erudite source, the church of *Nossa Senhora do Carmo*, built at the same time and sharing builders and knowledge, blurring boundaries between vernacular and erudite.

1 INTRODUCTION

Fuzeta is located in the eastern Algarve, on a beach that extends up to a small hill, on the west bank of the mouth of the Ribeira do Tronco River. It is protected from north winds by mountains, and exposed to high temperatures and low rainfall, which are characteristic of Mediterranean weather (Feio 1949, 107). Its privileged location within the salt marsh region of Ria Formosa, near the *Barra da Fuzeta*, is that it is the only maritime waterway to the high seas between Olhão and Tavira. Its proximity to the cities of Faro and Tavira, made Fuzeta a strategic point. Since the 16th century, the region has been protected by watchtowers, with the one closest to Fuzeta located in Bias, later reinforced by the Battery of Fuzeta, built in the 17th century (Vaz 1986, 8–10).

Urbanism of Fuzeta dates from the 16th century with the first fishermen seasonal settlements in huts located at the beach on the west side of the river, which became permanent due to the enhanced security provided by the construction of the battery. In the second half of 16th century, it was already considered a place of residence (Mascarenhas 1953). The dwellings were displayed in parallel rows facing the sea, creating a proto-orthogonal grid enclosed by the outer streets. The 18th century legislation contributed to the regularity of the Fuzeta's urbanism. Particularly, the law of 1776 which related to the calculation of rent in county lands. It recommended standardization of the size of the allotments and the prevalence of regular streets. This condition is visible in the regularity of the lot fronts of 19th century allotment campaigns, contemporary with the construction of most buildings of the historical centre (Pacheco 2018, 293–7).

This paper aims to characterize, analyze and compare the typology of the Fuzeta houses covered by vaulted terraces and to place and frame their constructive system in the tradition of the building treatises and the erudite buildings influences. The work also aims at discussing the importance of the transmission of erudite constructive knowledge into popular building practices and techniques. As there are no previous publications about the urbanism or architecture of Fuzeta, the study is based on in situ works, which included conducting house-to-house surveys of 140 houses.

2 VAULTS IN CONSTRUCTION HISTORY

The discipline of construction history still has little research on the construction of vaults in vernacular houses before the diffusion of materials and construction processes introduced by industrialization. Apart from few authors (Caldas 2009, 2012; Luna 2009; Rei & Gago 2016a, 2016b), studies on vernacular vaulted houses in the Iberian Peninsula are scarce, with the exception of some interest in noble houses and in religious architecture, in particular medieval architecture with an erudite root (Ramalho et al. 2002). These studies have generic approaches in the field of art history, sometimes specific in the framework of the rehabilitation of structures and pathologies. Archaeology and ethnology have also shown some interest in rudimentary vaulted buildings, and in buildings to support rural activity, while the vaults as a construction system used to cover current houses remain to be studied.

Until the end of the 19th century, vault construction was widespread throughout Europe, in erudite and vernacular constructions, about whose knowledge was

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disseminated through structural calculation manuals, as happened in Portugal. In the international context after the Industrial Revolution, it gradually slowed down, at the same time that the first patrimonial views of vaulted buildings started to emerge.

Auguste Choisy (1841–1909), engineer and architectural historian, was one of the first researchers to investigate the constructive system of vaults. His study of notable constructions by the Roman and Byzantine civilizations and the knowledge acquired through direct contact with the buildings resulted in the following books: *L'Art de bâtir chez les Romains* (1873), *L'Art de bâtir chez les Byzantins* (1883), and the *Histoire de L'Architecture* (1899). In these publications he highlighted the differences between vault systems according to geometries, construction processes and materials used (Choisy 1883).

According to Choisy, the Romans used different types of systems to build a vault, all requiring the use of a removable wooden formwork that guaranteed the geometry: i) the vault made of a concrecional material on the formwork; ii) the vault in stonework with the stones assembled in a formwork; iii) the vault with lost formwork; and iv) the vault made by bricks assembled in the formwork and filled with a concrete material. Therefore, the Roman brick vaults, with a concrecional conception, differs from the Byzantine brick vault that does not require the use of formwork during the construction process due to the way the bricks are assembled between themselves, from the walls to the closure, generating the intrados (Choisy 1883, 19).

In the Roman system, the brick vaults are built by rows perpendicular to the front wall and with bricks placed with the stretcher face seen which requires the use of a formwork. In brick vaults built without formwork, classified by Choisy as a "Byzantine system", the rows are inclined over the front wall and the bricks are also placed with the stretcher face seen. The inclination is given by the placement of the bricks, more accentuated at the base than at the top, which causes a curvature that increases stability and prevents the sliding effect. The two construction processes in rows perpendicular or inclined in relation to the front wall, can be combined in the same vault, starting with perpendicular rows. The front wall in the springing that does not need the formwork due to the little curvature, is completed with rows of bricks inclined against the front wall. This is a solution with practical advantages and currently used in the Byzantine constructions (Choisy 1883, 34–6).

Some authors relate the development of the construction process of the vaults without formwork with the scarcity of timber (Ribeiro 1961; Villalba 1995) and others justify its presence in the Iberian Peninsula as the inheritance of Syrian civilization (Luna 2009, 494). In Portugal, there is an interpretive trend, formed in the transition from the 19th to the 20th century, regarding the cultural aspect of vaults and terraces construction, which defends a hypothetical persistence of the constructive uses of Islamic origin in the Portuguese fringe of the south-west peninsular. This trend still prevails today, mainly in tourist publications, although it is not supported by historical studies or scientifically based.

Contrary to what has been argued by Orlando Ribeiro (Ribeiro 1961), the vaults of the Modern Era only began to be used in aristocratic houses of the Algarve in the mid-18th century, and were probably first employed in common houses at the end of the same century. Despite the logic of a natural transfer over the centuries of knowledge across the Mediterranean Sea from the East to the West, there remains a hiatus of significant construction examples that relate to the examples known in Portugal built between the 18th and 19th centuries (Caldas 2007; 2009, 2012).

In Portugal, the buildings with the oldest vaults date to at least the Roman period, as, among others, the vaults of the cryptoportico on *Rua da Prata*, in Lisbon, built between 1st BC and 1st AD centuries. In Baixo Alentejo, other Roman vault examples were built in the *villa* of São Cucufate, in Vila de Frades, Beja, before the 4th century. The same system is found in the São Bento chapel, in Monsaraz, built in the late 16th and early 17th centuries, attesting to the permanence of constructive knowledge in the region.

One of the first Portuguese publications referring to the constructive process of the vaults was the manual of the architect João Nunes Tinoco (ca. 1610–89) entitled *Taboadas gerais para com facilidade se medir qualquer obra do officio de pedreiro, assim de cantaria como de alvenaria, com outras varias curiozidades da geometria pratica* (General tables to easily measure any work of the mason, as well as stonework or masonry, with other curiosities of practical geometry) (1660). The manual provides geometric notes for the construction of double (*dobradas*), simple (*singelas*) and lowered (*abatidas*) brick vaults, specifying the necessary materials and procedures in tables and drawings. The manual has sections dedicated to the construction of vaults: "How is it known how many a *braça* [old measurement unit correspondent to two open arms, around 2.2m] bricks to use in a double or simple vault?" (Tinoco 1660, 34); "Form of lowered vaults (*sarapaineis* or *abatidas*) by the 5th part and by the 6th part" and "Form of lowered vaults by the account of the 3rd and 4th part" (Tinoco 1660, 43).

Tinoco's tables appeared at a time when the teaching institution *Aula de Fortificação e Arquitetura Militar* (1647–1709), based in *Paço da Ribeira*, in Lisbon, encouraged both the translation of foreign works representative of the most advanced defensive systems; and the publication, in Portuguese, of specialized works, marking the beginning of a new way of teaching Military Architecture. In this context, Luís Serrão Pimentel (1613–79), senior royal engineer since 1671, and teacher of Fortification in the Mathematics and Fortification Class, developed the *Methodo Lusitanico* (Lusitanian Method) (1680) to support his classes and teach how to draw regular and irregular fortifications.

Later, in the 18th century, in the framework of the Enlightenment, several international publications

emerged revealing concerns about the graphic representation of arches and vault sections. In addition, printed works dedicated to ornamentation, measurements, regulations, and standard specifications, helping to unify the measurement units and methods emerged. At the same time that general treatises and manuals of perspective and drawing appeared, a new category of works dedicated to the mechanics of arches and vaults featured in the Enlightenment thinking (Mateus 2002, 40). In Europe, the treatises sought to respond jointly to the requirements of architecture, civil engineering and military engineering. This is the case of *O Engenheiro Português* (The Portuguese Engineer) (1728–9), written by Manuel de Azevedo Fortes intended for teaching at *Academia Militar da Corte* (1707–79). In book V, entitled "Effective fortification" the question of waterproofing the vaults is addressed, among other topics.

Contemporaneous to the construction publications of the European vanguard, another Portuguese manual was written, *Advertências aos Modernos que Aprendem o Ofício de Pedreiro e Carpinteiro* (Advertences to Modern Learning in the Profession of Mason and Carpenter) (1757), by the master Valério Martins de Oliveira. This manual aimed to transmit knowledge about the art of building through traditional and learned processes, and brought together the work of Renaissance architects to the Portuguese construction panorama, such as the arch of Sebastião Serlio published in the architectural treatise *Tutte l'opere d'Architettura et Prospettiva* (1537-early 17th century) (Oliveira 1757, 41). The Martins de Oliveira manual compiles erudite knowledge for practical transmission about construction planning, measurements and quantifications of bricks for different types of vaults – doubled, simple, in stone, in brick, groined, in brick with round turn to the way of barrel, lowered, hemispherical, through geometric drawings and tables (Oliveira 1757, 26, 28) (Figure 1).

In 1896, a new manual was published entitled *Curso Elementar de Construções* (Elementary Construction Course) by Luiz Augusto Leitão. The chapter "Construction works: Masonry walls, walls and stone vaults (…) and vaults formwork", addresses the different types of vaults and their regional nomenclatures (lowered, sail (*asa de cesto*), cloister and hemispherical with pendentives) and their construction processes (Leitão 1896, 251–3). The vaults' construction procedures refer, among other issues, to the use of formwork and to the specificity of the vaults and brick vaults of the type *abobadilha* (barrel, groined (*abobadilha de percinas*), cloister (*abobadilha de engras*) and vaults from Alentejo region that "do not require the use of formworks or supports of any nature" (Mateus 2002, 77–8).

3 THE VAULTED HOUSES OF FUZETA

There is no documentation giving the date of the construction of the first houses in Fuzeta. However, according to the similar context of the nearby village

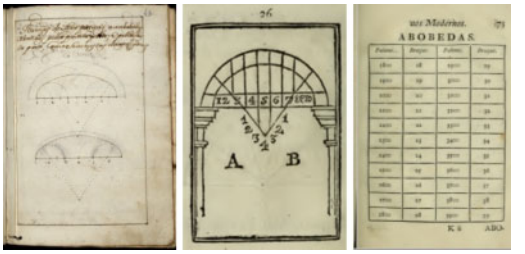

Figure 1. (left) Three-centred arch profile geometry (Tinoco 1660, 43); (center) Arch of Sebastião Serlio; and (right) Table of vaults' measurements (Oliveira 1757, 26, 75).

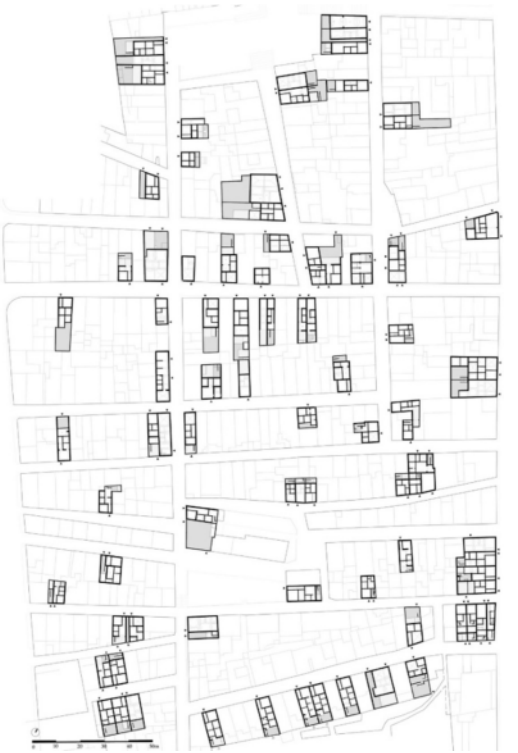

Figure 2. Fuzeta urban centre (western side of *Rua da Liberdade*) with the ground floor plan of the vaulted houses analyzed (author's drawing).

of Olhão, where huts began to be replaced in 1715 at residents' requests "to build masonry houses since they lived in huts" (Romba 2015, 56–7), in Fuzeta the replacement of huts happened also during the 18th century (Vaz 1986, 16).

The construction of masonry houses in Fuzeta, whether original or to replace huts, was associated with a current house type, corresponding to contiguous dwellings with a single floor, located in lots currently with homogeneous widths, around five to six *varas* (5.5m to 6.6m) in the standard lots (Figures 2 and 3).

The houses have a modular composition, organised in two or three sectors – façade, middle and back – with individual brick vault ceilings with terraces above

covering the majority of rooms, except the main room in the façade sector that was sometimes covered by a pitched roof (*telhado-de-tesouro*) currently absent. The main façade of the houses in standard lots is composed by two windows and a door, topped by a frieze protecting and hiding the terrace and covering the constructive systems.

The houses in standard lots can be composed of two or three sectors, usually the middle one is covered by lowered barrel vaults perpendicular to the façade and the back one with a parallel lowered barrel vault. On the façade sector is the living room, called *casa de fora*, with a square layout covered by a pitched roof, a sail vault (*abóbada de vela*) or a cloister vault (*abóbada barrete de clérigo*), and a corridor covered by a lowered barrel vault. The middle sector consists of two or three alcoves covered by a continuous lowered barrel vault, an interior living room, called *casa de dentro*, and a kitchen, usually in the back sector covered by a lowered barrel vault parallel or perpendicular to the previous sector. The indoor kitchen may be complemented by a covered outdoor space with a fireplace and oven, embedded in the roof terrace's stairwell, extended by a porch to the back courtyard, frequently where there is a water well (Figure 4).

The houses in narrow lots, with less than 5m front, are also composed by two or three sectors. The difference stands in the façade sector, without corridor and just the main room *casa de fora*. The middle and back sectors are covered by lowered barrel vaults perpendicular or parallel to the façade.

The house settled in large lots, with greater than 6m front or resulting of the junction of two standard lots is composed of two or three sectors.

It has an internal distribution with a central corridor, similar to the Portuguese traditional house called *risca ao meio* (symmetrical plan and façade), and has also a symmetric façade composed by a door in the middle flanked by one or two windows, and a courtyard in the back, depending on the geometry and location of the lot. The façade sector made up of two rooms, the living room and the bedroom, is covered by cloister vaults and separated by a corridor with a lowered barrel vault. The middle sector is covered by two continuous and parallel lowered barrel vaults, one covering the bedrooms or alcoves; and other covering the interior living room (*casa de dentro*) and the kitchen. These types of houses have a modular character emphasized by the independent vault coverage of the rooms with the extradoses identified on the terrace. The curvature of the extrados was softened by filling the spandrels, and lined with plain ceramic tiles or lime washed, ensuring insolation, and allowing its use.

The constructive system of the vaults as structure of the terrace is suitable for the Mediterranean environment. The terrace is an extension of the house used for domestic and fishing activities, in particular for drying fruit, fish or clothing, maintenance and storage of fishing gear, as well as for collecting rainwater stored in underground cisterns. Also, the thermal inertia of the vaults provides a positive thermal balance

Figure 3. Fuzeta urban centre (eastern side of *Rua da Liberdade)* with the ground floor plan of the vaulted houses analyzed (author's drawing).

between indoor and outdoor temperature and humidity (Pacheco et al. 2015).

According to the vault terminology used by Mascarenhas Mateus (2002, 82–4), the brick vaults on the Fuzeta houses belong to the category of "ordinary masonry" (as opposed to "concrete masonry" molded on formwork filled with concrete and mortar). Lowered barrel vaults or lowered hemispherical vaults (sail vault) can be considered as "simple" type. Cloister vault with a square base and obtained by the intersection of two lowered barrel vaults are "composed" type. The choice of the arch profile results from several factors: the function of the vault; the dimension of the span to be overcome and the section and height of the support wall (pier); the volume of masonry and the charge supported by the extrados; the type of masonry used; and the available manpower (Mateus 2002, 8, 80).

The lowered barrel vaults in the houses of Fuzeta are built in brick with the stretcher face seen, according to a process that does not use a formwork for placing the bricks. Those are placed in inclined rows in relation to the front walls, similar to the Byzantine system for building brick vaults described by Choisy (1883). The springer (area of the beginning of the intrados curvature) is made with stone masonry, arranged conically in straight rows perpendicular to the front walls, supporting the staring of the curved rows of brick, placed with the stretcher face seen, and oblique

Table 1. Vaulted houses and lot typologies according to the "house-to-house" surveys covering 140 houses in the urban centre of Fuzeta village.

Lot typology	House typology	n°	%
	2 sectors, the middle one covered by lowered barrel vaults perpendicular to the façade	37	27
Standard lot (between 5m and 6m front)	3 sectors, the middle one covered by lowered barrel vaults perpendicular to the façade and the back one with 1 lowered barrel vault parallel to the façade	17	12
	2 or 3 sectors, the middle one covered by lowered barrel vaults parallel to the façade	10	7
Narrow lot (less than 5m front)	2 or 3 sectors, the middle one covered by lowered barrel vaults perpendicular to the façade	36	26
Large lot (more than 6m front) or 2 standard lots joined	2 sectors	10	7
	3 sectors	17	12
	House without typology	3	2
	Warehouse	10	7
	Total	140	100

in relation to the front walls, where the arch profile is drawn (Mateus 2002, 91–2). The slope of the first brick rows in direction to the front wall is maintained along the length of the vault, giving stability when transmitting loads to the side and front walls, ensuring that the arch pressure line is within the thickness of the vault. The intrados consists of rows of bricks placed with the stretcher face seen, filled with concretion material of sands, lime mortars and various inert, including shellfish contributing to the insolation, reaching more than 80cm of thickness, decreasing to the top of the vault with just over 30cm, corresponding mainly to the thickness of the bricks and the extrados coating on ceramic tile.

The type of brick assemblage of the vault construction is mainly imposed by the construction method. In the execution of the last part of the barrel vaults, in the central area, is used a spine assembly method, in which each brick is assembled from the perimeter, ending in the centre (Choisy 1883, 39).

In the sail vault construction, the assemblage of the bricks is carried out with a slight inclination composing concentric rings over the springers made by limestone masonry. Occasionally, small blocks of the same stone appear in rows between the bricks (Figure 6). On the top of the vaults, in the last rows the bricks are placed perpendicular to each other.

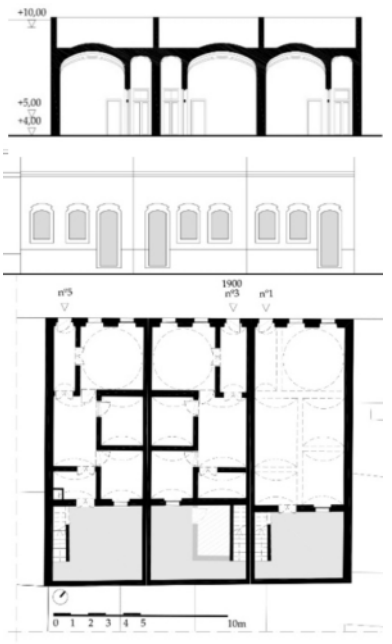

Figure 4. Elevation, section and ground plan of the set of houses located in standard lots in *Travessa das Amoreiras* (author's drawing).

In the cloister vaults, two types of brick assemblage are combined: lying bricks composing the two crossed arches shaping the geometry of the vault, and bricks standing vertically filling the intrados (Cabral & Aranha 1996; Mateus 2002, 93–5) (Figure 6).

Traditionally, the intrados of the vaults is finished with plaster and stucco, and often decorated with friezes and ornaments that enhance the geometry of the vault, although hiding the stereotomy of the bricks' assembly in rows. Frequently, the rehabilitation works carried out in the last decade have removed the interior coating, leaving the bricks and the laborious assembly work seen.

In fact, the constructive process of the vaults of the Fuzeta houses is a knowledge based on an oral and practical tradition, whose calculations were made using empirical rules and methods based on geometric proportions compiled in tables (Mateus 2002, 133). This dimensioning process was the only existent technique until the end of the 17th century, when the first applications of Mechanical Engineering to the study of the structural performance of vaults appeared. Its use continued until the 20th century, coexisting with other more advanced techniques based on logarithmic calculations.

The rules contained in the tables were applied to the main structural elements: arch, vault and pier height (supporting wall); to the profile of the arches (once the vaults were classified by their representative arches – round, lowered or pointed); and the type of masonry (stonework, brick or concrecional) (Mateus 2002, 131).

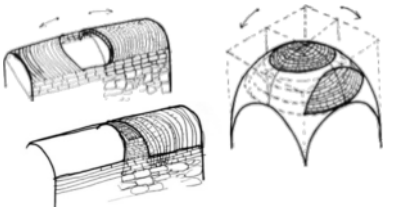

Figure 5. Scheme of the constructive systems of lowered barrel vault (left) and sail vault (right) (author's drawing).

The stability concept of the arches and their piers (*pé-direito*) is studied in a simplified and synthesized version, according to two extreme moments: the "shoot down" moment, caused by the impulse transmitted by the arch and proportional to its thickness; a "stabilizing" moment proportional to the weight of the piers.

Also, the calculation of the vault's thickness, constant or variable, was done according to empirical rules, as mentioned in the works of Francesco Milizia, *Principii di architettura civile* (1781), by Girolamo Masi, *Teoria e pratica di architettura civile per istruzione della gioventu specialmente romana* (1788) and Charles Leroy, *Traité de stéréotomie* (1877). The thickness of the support walls of the vaults is also determined empirically, based on geometric constructions that considers the span distance, the profile of the arches and their peers. According to Gustav Adolf Breymann, in the treatise *Allgemeine Bau-Constructions-Lehre* (1849), the rule has a medieval origin. Its first representation is due to François Derand in *L'architecture des voûtes* (1643), later included in several treaties: in the *Cours d'architecture*, by François Blondel (1675–83), in the treaties previously mentioned by Francesco Milizia (1781) and Girolamo Masi (1788), and also in the *Traité théorique et pratique de l'art de bâtir*, by Jean-Baptiste Rondelet (1804).

The traditional method used to calculate the thickness of the supports of the vaults implied the difference of thrusts caused by different types of profiles (although it disregards the materials' resistance, the voussoirs' thickness, the loading system and the height of the piers). Breymann determines that the thickness of the walls of the brick barrel and lowered barrel vaults is 1/4 of the span (L), with a rise greater than 1/8 of the span (L) (Mateus 2002, 132–3, 135).

Rondelet's studies contributed to 19th century treatises due to their easy application through formulas and graphic schemes, although with methodological limitations and simplified calculations. In the chapter *La Théorie de Voûtes* (section VI of Book IX) of *Traité théorique et pratique de l'art de bâtir*, Rondelet presented empirical formulas for determining the thickness of barrel vaults using reference values for lowered or pointed arch profiles, based on the tests carried out at the end of the 19th century by M. Lavezzari and presented by Marcel Daly in the Portuguese magazine *Construção Moderna* in 1900. (Mateus 2002, 142).

4 THE GEOMETRY OF VAULTS: A CLUE TO ITS ERUDICITY

The lowered barrel vault is the most common type of vault used to cover the rooms of the Fuzeta houses, also used as structural support of the terraces. Lowered barrel vaults, in which the rise is less than half the span are vaults in an arch of a circle or three-centred arch (Leitão 1896, 252). The lowered barrel vault can have different arch profiles obtained from different geometries: round, semi-elliptical or lowered, the most common. The lowered arch is outlined from an odd number of circumference arches, joined tangentially. The lowered arch profile is used when the ratio between the span (S) and the rise (R) varies between 2 and 5 ($2 < S/R < 5$). The simplest lowered arch profile is composed by the three-centred and used when the ratio between span and rise varies between 2 and 3 ($2 < S/R < 3$) (Mateus 2002, 82).

Geometrical studies of the arch profile in 30 rooms of Fuzeta houses were carried out based on *in loco* measurements and further geometrical construction following the traditional treatises (Pacheco 2018; 224–6). According to this approach, the arch profiles of the lowered barrel vaults have different ratios between span and rise (S/R): around two, with greater rise and almost a round arch, others closer to five, with lesser rise, with a more lowered geometry. The most common ratio between span and rise varies between three and five, and corresponds to most of the vaults, including the oldest ones. Ratios greater than five refer to semi-elliptical arches whose geometry appears occasionally in vaults that are more recent or with larger spans, as well as some vaults with profile arches based on segments of circumference (Figure 6).

The lowered barrel vault is present in all sectors of the house, with different ratios between spans and rises according to the dimensions of the compartments. The set of lowered barrel vaults supports most, or all, of the roof terrace. The vaults with narrower spans are found in the corridor covered by a vault with a lowered barrel, located in the sector of the façade. In the middle sector, the lowered barrel vaults that cover the alcoves have spans around 2m. The room *casa de dentro*, also in the middle sector, and the kitchen in the back sector are also covered by lowered barrel vaults, with spans of various dimensions, upper 2m (Costa 1971, 12).

The sail vault is related with square layout compartments, which vary between 2m and 4m in span, and are found mostly in the *casa de fora* and *casa de dentro*, but also can appear in the alcoves. These vaults do not present a risk of collapse in their construction: once during the process each of the rings that composes the geometry, is closed before starting the next one. Also, the assembly of the bricks inclined in each row, convert the vaults into a stable element that "do not give horizontal impulse because they charge vertically on the piers" (Leitão 1896, 91; Villalba 1995, 91) (Figure 5).

Less common is the use of the cloister vault, "the reverse construction of the groin vault" (Costa 1971, 13). It results from the intersection of two-barrel

Figure 6. (top) Intrados and extrados of the sail vaults located in the main room *casa de fora*; (middle) Intrados of cloister vaults in the main room *casa de fora*; (below) Geometrical construction of arch profiles of lowered barrel vaults with three-centred arch, based on *in loco* measurements (author's photos).

vaults, preserving the imposts at the same level, allowing cover of the regular plant spaces with four or more sides, meeting at the same closing point. Its use in Fuzeta houses is associated with a more recent type of housing, built in the transition from the 19th to the 20th century, as roof coverage of the two *casas de fora* built on lots with large fronts or two regular jointed lots.

The use of vaults as a roofing system for the current house is not exclusive to Fuzeta; although it is there that its use occurs to a greater degree. Vaulted houses are also found in the neighbouring towns of Moncarapacho and Olhão and in rural areas of inner Algarve, where the vaults are used either as terrace support or as a floor support of the first floor, or just as a specific cover for a certain compartment. However, its geographic scope has yet to be studied.

As it seen previously, most of the vaults were built from the second quarter of the 19th until the first half of the 20th century, contemporary with the beginning of the church of *Nossa Senhora do Carmo* construction, which replaced the pr imitive chapel (Figure 7).

The use of vaults as a roofing system for the current Fuzeta house is implicitly related to the opportunity created by the presence of master builders in the village during the construction of the church, and the functionality of terrace use in the everyday life of a fishing village. The vaults' intrados show an excellent mastery of the constructive technique, observed in the geometry of the vault and in the precise placement of the bricks in the rows and coatings. Therefore, the construction of the church was a key moment and the main

Figure 7. Lowered barrel vault in the church of *Nossa Senhora do Carmo,* in Fuzeta.

cause of the dissemination of the erudite constructive knowledge used in current houses.

The geometries and the constructive processes used by vault master builders reinforce the hypothesis of the transmission of a constructive knowledge from an erudite source to a popular context. The lowered barrel vault, the most common geometry covering the middle and back sectors of the houses is built according to a three-centred profile arch, already mentioned in the 17th century Portuguese buildings' manuals. The sail and cloister vaults, intentionally covering the main rooms *casa de fora* and *casa de dentro*, are the pinnacle of erudite construction in this fishing village.

5 CONCLUSIONS

The unprecedented study of Fuzeta's vernacular vaulted houses, based on 140 surveys, aimed to characterize, analyze and compare its types, to understand the relationship between constructive systems, the geometries of the vaults and the use of the rooms. Since no documents or registers related to the houses or vault constructive systems or chronology were found, the question about the origins of these vaults and who built them was raised.

Placing the Fuzeta vaults in the history of construction, mainly due to their study through the buildings' treatises approach, allowed placement and framing of its constructive system in the field of erudite buildings influences. These vaulted houses are a testimony of the anonymity of the local masters who built them and about whom there is no information. The only plausible clue was found in the most erudite building of the village, the local church. The forms and construction processes of the church inspired, influenced and may have been intended as an example to be emulated in the popular houses.

The erudite features transmitted locally are reflected in the accuracy of the arch profile geometries (drawn by geometrical knowledge of construction manuals), in the precision of the laying of the bricks, and in the excellence of intrados surface coating. These features are distinct from other Mediterranean vaults with a more popular origin, usually made by concrecional processes based in the use of formwork and volcanic stones, which tend to have approximate geometries and rustic coatings. In addition, the need for new dwellings, and the replacement of precarious huts, took place during the 19th century, and

led to the construction of houses with laboured constructive processes (particularly the vaults) and to use standardized architectural typology adapted to the homogeneous allotments. These sets of houses, forming urban ensembles, using erudite constructive systems and standardized dimensions, suggest they were part of a projected plan. Nevertheless, research carried out at main archives (municipalities of Tavira and Olhão and district of Faro) discounted this hypothesis once no building request documents were found. The constructive influence attenuates the popular origins, fomenting a cultured appearance to the village. The study of Fuzeta's vaulted houses and their underling geometries, constructive systems, materials made by anonymous builders, contribute to a deeper understanding of empirical knowledge transmission. Further, it establishes the importance of these constructive systems in the history of traditional architecture and construction within the wider context of the Algarve and Mediterranean region and raises the question of the difficulty in establishing boundaries between popular and erudite knowledge, bridging these two terms, usually perceived as being opposites.

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REFERENCES

Breymann, G.A. 1849. *Allgemeine Bau-Constructions-Lehre.* Stuttgart: Hoffmann.

Cabral, J. & Aranha, J. 1996. *Abóbada Alentejana. Guia do Formador*. Lisboa: Euroqualification/CENFIC.

Caldas, J. 2012. The Use of Vaults in the Reconstruction of Pombaline Downtown Lisbon. In *Nuts & Bolts of Construction History*, vol. III: 495–502. Paris: Picard.

Caldas, J. V. 2007. *A Arquitectura Rural do Antigo Regime no Algarve.* PhD thesis, vols. I, II. Lisboa: IST, UTL.

Caldas, J.V. 2009. El uso de la bóveda en la vivienda portuguesa de construcción tradicional. In *Actas del Sexto Congreso Nacional de Historia de la construcción*, vol. II: 1447–1456. Valencia: Instituto Juan de Herrera/ETSAM,

Choisy, A. 1997 [1883]. *El arte de construir en Bizancio.* Madrid: Instituto Juan de Herrera/CEHOPU.

Feio, M. 1949. *Le Bas Alentejo et l'Algarve*. Lisboa: CIG.

Luna, M.F. 2009. Origen de la bóveda tabicada. In *Actas del Sexto Congreso Nacional de Historia de la construcción,* vol. I. Valencia: Instituto Juan de Herrera/ETSAM.

Mascarenhas, J.F. 1953. A origem do topónimo Fuzeta e a sua evolução. *Jornal Correio do Sul*, 10 Setembro .

Mateus, J.M. 2002. *Técnicas tradicionais de construção de alvenarias. A literatura técnica de 1750 a 1900 e o seu contributo para a conservação de edifícios históricos*. Livros Horizonte.

Oliveira, V.M. 1757. *Advertências aos Modernos que Aprendem o Ofício de Pedreiro e Carpinteiro*. Lisboa: Academia Real.

Pacheco, M. 2018. *Fuzeta – Um núcleo urbano piscatório singular.* PhD thesis. Lisboa: IST/UL.

Pacheco, M., Tomé, A. & Gomes, M. G. 2015. Fuzeta's vaulted houses. A thermal performance study. In *Proceedings of Latin-American and European Conference on Sustainable Buildings and Communities*, vol. I. Guimarães: Multicomp.

Pimentel, L.S. 1680. *Methodo Lusitanico de desenhar as fortificaçoens das praças regulares, & irregulares, fortes de campanha, e outras obras pertencentes a architectura militar distribuido em duas partes operativa, e qualificativa.* Lisboa: Antonio Craesbeeck de Mello Impressor de S. Alteza.

Ramalho, J.F., Pestana, J.A., Lamas, A.R.G., Gago, A.S.& Duarte, C. 2002. Intervenções da DGEMN. *Monumentos 17: Igreja e Convento de São Francisco, Évora*. Lisboa: DGEMN.

Rei, J. & Gago, A.S. 2016a Arcos e Pés-direitos. Regras de Dimensionamento na Tratadística/2016b Arcos e Pés-direitos. Regras de Dimensionamento na Tratadística. In *2° Congresso Internacional de História da Construção Luso-Brasileira:* 91–104, 105–118. Porto: FAUP

Ribeiro, O. 1992 [1961]. Açoteias de Olhão e Telhados de Tavira. Influências orientais na Arquitectura Urbana. In *Geografia e Civilização. Temas Portugueses*. Lisboa: Livros Horizonte.

Romba, S. 2015. *Evolução Urbana de Olhão.* Olhão: Sul, Sol, Sal.

Tinoco, J.N. 1660. *Taboadas gerais para com facilidade se medir qualquer obra do officio de pedreiro, assim de cantaria como de aluenaria, com outras varias curiozidades (…).* s/l.

Vasconcelos, J.L. 1975. *Etnografia Portuguesa,* VI. Lisboa: INCM

Vaz, A. 1986. *As Origens da Fuzeta e seu Topónimo*. Olhão: Biblioteca Cultural Olhanense.

Villalba, A.C. 1995. *Historia de la construcción arquitectónica*. Barcelona: Edicions UPC.