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Examination of earthen construction in archaeological sites of the Iberian Peninsula for risk analysis

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Abstract
Earthen constructions are one of the most widespread and fragile elements of the architectural heritage of the Iberian Peninsula. This situation is worsened when they lack the necessary protection and are found in vulnerable enclaves such as archaeological sites. Their geographical, cultural and constructive particularities expose them to different risks – natural, social and anthropic – which threaten their conservation and interpretation for future generations. This study aims to examine this type of heritage complex in constructive terms, focusing on constructions of a domestic and productive nature and paying special attention to those from prehistoric, protohistoric and Roman periods. Attention is also paid to later similar remains conserved. Quantitative and qualitative analysis methodologies are applied to a series of case studies found throughout the Iberian Peninsula in order to record the information on fiches examining general and specific aspects of the different techniques observed. Given the broad timeline and geography covered, as well as other identification and conservation factors, the data collected reflect a predominance of adobe over other earthen techniques which are also described, including daub, cob and rammed earth, with fewer examples identified throughout. This heritage is therefore classified to record the original states compiled from the different archives, reports and publications. Subsequently, a specific database is generated for the analysis of risks (exposure and sensitivity) and criteria, strategies or results (capacity for adaptation), gleaning as much information as possible from these characteristics.

Keywords: *heritage; archaeology; techniques; typologies; adobe; rammed earth.*

1. Introduction

Earthen construction is understood as any elements built using earth as a main component, whether for structural purposes or other domestic and production functions related to ways of life and needs. Despite lacking major resistance or bending properties in its raw state, earth has been a prime common resource from the earliest of times, due to its abundance and availability. Constructive tradition progressively perfected its execution, substantially improving mechanical and physical properties following experimental and physical criteria which provided a better response to the risks threatening the conservation and maintenance of earthen architecture.

The climate and geology of the Iberian Peninsula made it an ideal location for the widespread proliferation of this type of construction throughout prehistory and protohistory. In conjunction with the influences derived from historic events such as the Orientalizing period (Belarte, 2011), the Roman era and the Middle Ages, this brought about the proliferation of different historic types and techniques.

This information is now presented through the remains in archaeological sites, often found incomplete due to the speed at which they are being lost as these are complexes extremely vulnerable to exposure and abandonment (Pastor, 2017).

These techniques have been studied and generally defined by different authors in recent publications such as M. Pastor (2017) as well as in the late 20th century, by A. Sanchez, (1999). However, interest in earthen constructions in the field of archaeology had begun a few years earlier through studies like that by C.A de Chazelles and P. Pouet (1997), when attention was drawn to the fragility and neglect of earth as a material compared to others such as stone, generally recognized as more durable and resistant. It is this interpretation of earth as a non-renewable finite resource, exposed to different forms of deterioration, which has led to growing interest and documentation and interpretation processes since the late 19th century (Matero, 2013).

2. Objectives and methodology

In order to analyse risks and vulnerabilities within this theoretical framework, research is undertaken as part of the project "*RISK-Terra. La arquitectura de tierra en la Península Ibérica: estudio de los riesgos naturales, sociales y antrópicos y estrategias de gestión e incremento de la resiliencia*" ["*RISK-Terra. Earthen architecture in the Iberian Peninsula: study of natural, social and anthropic risks and strategies to improve resilience*"]. This aims to offer a picture of the variability of earthen constructive techniques and materials used in domestic and productive architecture within the Iberian Peninsula mainly during the prehistoric, protohistoric and Roman periods. In addition, some cases are conserved from later periods, when techniques such as rammed earth were disseminated and standardized. Knowledge of this original condition helps identify the percentage and scope of material loss of this heritage over time, while selecting the most interesting cases after cross-referencing the data relating to natural, social and anthropic risks for later consideration.

To do this a documentary database of case studies was established, each entry containing the general data (name, municipality, province, UTM ETRS89 coordinates, typology, chronology, current use, location plan, and general photograph) and constructive data (zone, constructive technique, stabilizers, as well as other techniques, and dimension data) which allow them to be classified.

Case study locations were identified from different sources, such as the excavation of sites with earthen techniques found in the archives of the IPCE [Cultural Heritage Institute of Spain] and other national publications, such as Excavaciones Arqueológicas en España: EAE and the Noticiario Arqueológico Hispánico; as well as publications and entries at regional level (i.e.. SIP of Diputación de Valencia, the Anuario Arqueológico de Andalucía, or the Mapes del Patrimoni Cultural Local de la Diputació de Barcelona); research projects (*SOSTierra: La restauración y rehabilitación de arquitectura tradicional de tierra en la Península Ibérica. Líneas guía y herramientas para una intervención sostenible*); and a range of reports from different excavations (Table 1).

IPCE	36	17%
Publications and reports	159	73%
National/regional documentation	23	11%
Total	218	

Table 1. Main sources for the identification of cases (Source: S. Manzano Fernández, 2022).

Efforts have been made to keep errors in classification to a minimum based on the problems of excessive simplification of categories (Chazelles & Poupet, 1985) discussed and analysed in the Iberian Peninsula (Pastor, 2017) (Sánchez, 1999), ensuring whenever possible to provide graphic and chronological documentation of the descriptive denominations of rammed earth, confused with cob or daub in pre-Roman periods.

In order to present dimensional statistical data care was taken to respect chronological periods and their variability using Kernel Smoothing - Density Estimation with a bandwidth of 0.8.

3. Data and case studies

The current database, with 218 cases of very different types, was compiled from a review of the bibliography. Most of the sites recorded (76%) are in isolated locations, more affected by natural risks. A further two types of locations can be identified at urban level: firstly, those in an unbuilt urbanized plot (9% of cases) and secondly, those within the urban layout (14% of cases) which are usually museumized or reburied following construction (Table 2).

Isolated	167	76%
In urban layout	31	14%
Isolated plot in city	20	9%
Total	218	

Table. 2. Location of case studies in current database (Source: S. Manzano Fernández, 2022).

Furthermore, the chronology for each of these earthen sites can be identified, offering relevant information on the constructive techniques and elements found. The standardization of materials and more resistant techniques leads to increased percentages of domestic and productive cases from the Late Bronze Age / Early Iron Age, with a total of 38% compared to the 64% found from the Iberian period and the 46% from the Roman period.

Currently, the percentage of representative cases from the Medieval periods, including higher proportions of techniques like rammed earth, which due to its particular proliferation, is identified in 9% of cases (Table 3).

Neolithic / Eneolithic	8	6%
Bronze Age	10	8%
Late Bronze Age / Early Iron Age	49	38%
Iberian	81	63%
Roman	59	46%
Medieval	11	9%
Total	218	

Table 3. Case study dating in the current database (Source: S. Manzano Fernández, 2022).

To some extent the geographical dispersion shows the absence of cases in areas with greater rainfall indices, as it is the drier areas where timber is scarcer which benefit from earthen architecture techniques. Location coordinate UTM ETRS89 H30 was entered into GIS systems to cross-reference different data for subsequent analysis (Fig. 1).

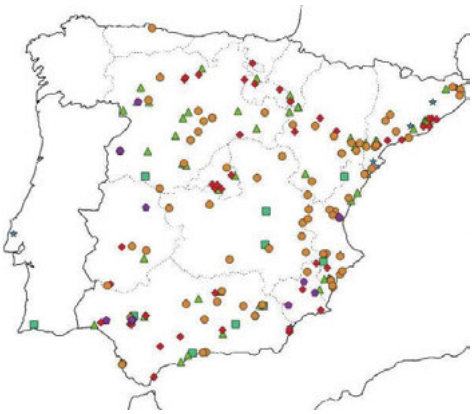

Fig. 1. Geographical location patterns of the case studies of the current database and chronological dating. Key: ★ = Neolithic; ■ = Copper Age / Bronze Age; ▲ = Late Bronze Age / Early Iron Age; ● = Iberian; ◆ = Roman; ⬟ = Medieval (Source: S. Manzano Fernández, 2022).

4. Constructive use

One of the data items recorded for the different case studies is the area in which these earthen constructions are used, as they are commonly found in structural elements as well as a wide range of solutions linked to the necessities of different ways of life. This is especially noticeable in periods such as the Iberian, when the use of earth as a main constructive material became standardized (Sánchez, 1999) giving rise to a wide range of typologies and pieces.

Wall elevation	135	62%
Flooring	104	48%
Elements for production	64	29%
Domestic elements	62	28%
Rendering	43	20%

Table 4. Presence of earth per element in the case studies in the current database (Source: S. Manzano Fernández, 2022).

Overall, the most frequently recorded element in case studies reviewed found in 62% of cases in different configurations, is wall elevations, with or without plinths. These are usually configured as a main element in domestic and productive architecture, but also as wall infill alongside other techniques in monumental architecture, although this is not covered in this study.

The next most recorded element, with 48% of cases, is flooring and related solutions, given the frequent use of earth for levelling and for the different finishes of rammed earth, beaten earth or adobe.

In the domestic space, non-structural elements introducing a wide range of pieces can also be found. 28% of cases incorporate earthen elements like benches, usually built into walls in the same material and length, and also found rendered or as modular solutions. In hearths, usually executed in clay or adobe, they are combined with other stone elements, defining a combustion perimeter (Abad & Sala, 1993) which can be found level, raised or sunken and eventually hardening, as seen in El Amarejo, in Cerro Redondo, and in Cortes de Navarra, both in stretcher and shiner bond. Other elements include mounds, outer rings of earth or adobe beside the small pebbles, occasionally covered in a pyramid shape, and other individual pieces such as the visible lintels in Las Casas del Turuñuelo, wells like those in La Indiana, shelves for ceramic goods in Cabezo Redondo, canals, chimneys, and oil presses.

Elements for production were also studied and found in 29% of total cases in a wide range of configurations. In terms of geometry, there are entries for kilns with different combustion chambers: circular, pseudo-circular, or oval, more or less elongated, with side or back supports, with central walls dividing the space into two or with a central pillar. In most of these earth is used to build the side walls, which are at times excavated from the earth in the ground and rendered in adobe. The grill, also in adobe and perforated for ventilation, was built on this structure and was usually made up of long pieces of mud and straw, flat on one side and convex on the other. These kilns were usually closed off using a false dome built with adobe courses (Luzón, 1973).

20% of cases incorporate rendering, regularly applied to protect all sorts of structures, from wall elevations to combustion chambers, which hardened when they were first fired. Different types of rendering identified, usually 2-7 cm thick, include mud and straw with a kaolin base, yellow and grey stucco, as well as paintings and decoration.

5. Analysis and characterization of the main constructive techniques

Although earthen construction has been documented both in mixed (Chazelles, 1997) and independent form, there are no examples of mixed earth constructions unaffected by collapse found in the Iberian Peninsula. These date from the earliest periods and are difficult to distinguish given their constructive similarity with roofing solutions used regularly in pre-Roman architecture (Sánchez, 1999).

This technique, daub (or *torchis* in French), is a mix of water and earth that cannot be separated from a timber substructure, which it covers, and serves as an internal load-bearing reinforcement (unlike conventional rendering) when increasing wall height or building roofs. Collapses of this sort have been identified in Neolithic sites such as Bòbila Madurell (Plasencia, 2016); in Late Bronze Age sites including Caramoro I (Jover, Pastor, Basso, et al., 2019) and Cerro de la Encina (Aranda & Molina, 2005); and in Iberian sites such as Tossal Montañés (Moret, 2001), to judge from the plant imprints observed on the surface. Traces of original daub are found in only 2.5% of cases reviewed.

Therefore, three main constructive techniques have essentially been identified in the case studies: cob, adobe and rammed earth.

5.1 Cob

Alongside the daub detailed above, cob (or *bauge* in French) is one of the oldest earthen techniques documented, the result of processes requiring minimal modification of the material, which can be prepared and handled on site. Considered the dominant technique of the 3rd and 2nd millenia along with daub, cob remained widespread until the Late Bronze Age (Chazelles, 1995). This technique, extensively described and documented, consists in the application of an earth and water mix, usually stabilized naturally by adding plant fibres such as straw, or anthropically using lime which dries to provide sufficient joint resistance to build load-bearing wall elevations from the base or plinth. This technique can be applied to all non-structural and homogeneous elements built without modulating, including beaten earth flooring; rendering; or other domestic constructions such as hearths, ovens, shelves and benches, built with similar characteristics and processes.

8% of the cases recorded in the current database appear to have been built with cob, although this technique is difficult to detect, often only identified by the finger imprints left during the production process. Examples of this can be found in the prehistoric cabin in Alcalar; in domestic walls with no plinth in the Rábita Califal of the Dunas de Guardamar (Azuar, Rouillard, Gailledrat, et al., 1998); in the mud shelves of Cabezo Redondo; or in wall elevations of Caramoro I, mentioned earlier, with clearly visible stacked damp earth balls (Jover, Pastor, Basso, et al., 2019). Some dubious registers are also observed, like the structures of Phase III of Cerro de la Encina (Arribas, Pareja, Molina, Areaga, & Molina, 1974) or those identified as adobe but whose ambiguous description and chronology suggest they could also be cob, like some structures in La Ereta de Castellar, Orpesa La Vella and Morro de Mezquitilla. Flooring with beaten and rammed earth is recorded in 47% of cases.

The dimensions of these elements vary widely with some cases of elevations 25-45 cm thick identified, while several domestic structures 10-15 cm thick are found. As is to be expected, all these examples conserved have been reduced to a few centimetres.

5.2 Adobe

Adobe, of complex origins, definitively appeared around the Late Bronze Age and Early Iron Age (13th to 5th centuries BC approximately) and became a major technique predominantly used throughout protohistory (Sánchez, 1999). All types of elements and structures became particularly standardized in Iberian settings. Unlike its predecessors, adobe (or *brique crue* in French) is usually a modular technique used to produce air-dried mud bricks in variable sizes produced with or without moulds.

This is the most frequently identified technique, with 189 case studies in the current database, 87% of the total recorded, including notable cases such as La Mata, Cancho Roano, Bílbilis, Libisosa, Casa del Acueducto de Tiermes and La Fonteta. Although as with cob it often used stabilizers such as straw, manure or lime to improve its properties, only 7% of cases have shown clear examples of these additions. Other additions observed in 4% of cases include the use of lime hydroxide, rough stones, ceramic, gravel, sand or absence of additives. Despite this, and according to the bibliography consulted, the majority of cases (88%) present no descriptive information in this regard.

In terms of the bond in elevations, flooring and equipment the placements are not usually in a set order, with many cases of stretcher bond, header bond, or several others in stretcher and header bond, generally depending on whether the walls were load-bearing, party or partitions, as well as others with no apparent logical order. Occasionally in the construction of walls a shiner bond was executed, placing the long side. This may be the case of La Celadilla de Ademuz, with some thicknesses of 15-17 cm but with practically unrecognizable pieces.

Analysis for usual measurements for executing adobe is complex as these vary widely based on numerous conditioning factors such as mould size, base thickness, manual execution or the transfer of constructive culture for each period and place (Sánchez, 1999). In spite of this, the data obtained for the different case studies have been grouped according to the three main periods of development of the technique (Late Bronze and Early Iron Ages, Iberian (5^{th} c. – 2^{nd} c. BC, approx.), and Roman (3^{rd} c. BC – 5^{th} c. AD, approx..) in the Iberian Peninsula, namely the following measurement ranges:

- Late Bronze Age / Early Iron Age: length 36-44 cm (44%); width 16-22 cm (38%); height 8-11 cm (60%).

- Iberian: length 36-44 cm (29%) and 28-36 cm (25%); width 28-34 cm (28%), 16-22 cm (23%) and 22-28 cm (21%); height 8-11 cm (61%).

- Roman: length 36-44 cm (29%) and 28-36 cm (25%); width 28-34 (50%); height 8-11 (76%).

From this it can be deduced that the dimensions of the older pieces tend to be around 40x20x9/10 cm, while in the Iberian and Roman periods the sizes are quite similar, 40x20/30x8/10 and 40x30x7/10 cm, respectively. Some relations could be established with research that have already been carried out in the Iberian Peninsula, in which the most widespread module in Western Europe was 40x30x10 cm, while the lengths of 50 cm would be more related to the Punic cubit (Asensio, 1995). Other dimensions such as 15x10x8 and 30x20x10 cm would be dated to older modules according to these studies.

There is a separate category for the special pieces mentioned earlier, like those supporting the grill in elements for production, which could measure up to 108x32x15 (Luzón, 1973) depending on the distance to the central pillar.

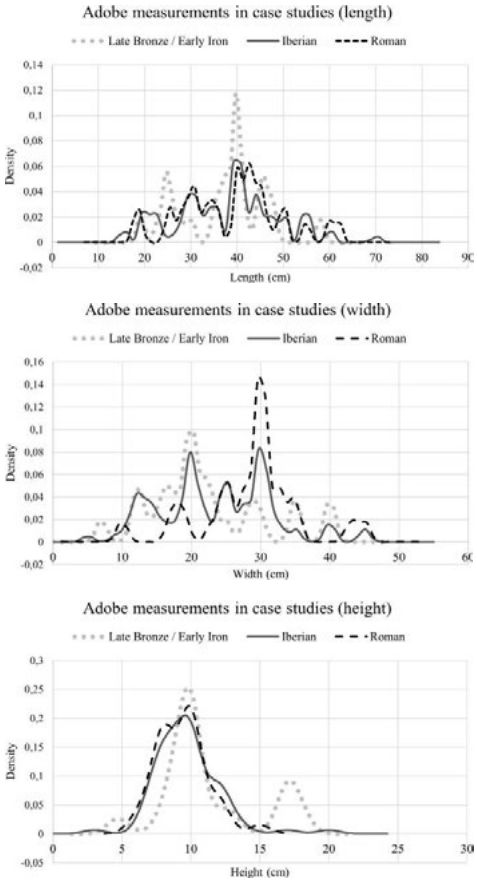

Fig 2. Most repeated dimensions according to Kernel density estimation of registered adobe (Source: S. Manzano Fernández, 2022).

Fig. 3. Earth hearth in the Iberian settlement of Coll del Moro (Source: S. Manzano Fernández, 2022).

Fig. 4. Earth craft structures in the Iberian citadel of Calafell (Source: S. Manzano Fernández, 2022).

5.3 Rammed earth

This technique (or *pisé* in French), as widely described and analysed as adobe, was consolidated in the Roman period although it pre-dated it (Sánchez, 1999). In the Iberian Peninsula the earliest recorded case is the domus in Ampurias (Chazelles, 1990). An earth rammer is used to tamp the earth in relatively thin layers, thanks to a mobile wooden formwork braced with transversal wooden pieces (putlogs). In this case these are stabilized through rammed earth instead of plant additives, although numerous typologies from later periods are found complemented with lime, stone and brick.

Given the extensive chronology analysed, the representation of case studies (10%) is discrete, including examples such as La Fonteta (Rouillard, Gailledrat, & Sala, 2007) and the Rábita Califal of Guardamar del Segura (Azuar, Rouillard, Gailledrat, et al., 1998), the dwellings of the castle of Niebla, and Libisosa. However, this percentage could vary if including the 4% of cases recorded prior to the example of Ampurias mentioned above, which gives rise to doubts regarding the excessive simplification described by Chazelles and Poupet, and mentioned earlier.

The measurements of this domestic architecture also vary considerably. The Roman rammed earth wall in Ampurias is 50 cm wide (Chazelles, 1990), a measurement close to the 47.5 cm observed in the Islamic Alquería of Bofilla. In contrast, the elevations of Medina Siyasa are 80 cm wide at the base of the wall (Navarro & Jiménez, 2011), close to the 85 cm of the Patio de San Laureano (Arenas, Carrasco, Conlin, et al, 2003). In the Comunidad Valenciana, the usual thickness found in rammed earth walls was between 40 and 90 cm (Font & Hidalgo, 1990) with a mould height of one metre, ranges observed in other cases of the Iberian Peninsula.

Cob		18	8%
	Signs of daub	5	
Adobe		189	87%
Stabilizers recorded	Plant	13	
	Others	4	
	Without stabilizers	3	
	Not specified	168	
Rammed earth		22	10% (6%)
	Rammed earth (possibly simplified category)	(9)	
Flooding (Rammed earth or beaten earth)		103	47%
Other techniques			
	Masonry	169	78%
	Ceramic brick	37	17%
	Flat stone or stone slabs	11	5%
	Pebbles or small pebbles	14	6%

Table 5. Distribution of constructive techniques observed in case studies from the current database (Source: S. Manzano Fernández, 2022).

5.4 Other techniques

Despite the presence of cases in which earthen elements spring directly from the flooring, which also tends to be earth (Azuar, Rouillard, Gailledrat, et al., 1998), due to its susceptibility to damp from capillarity it is usually combined with more durable techniques, particularly at the base or plinth. Of the cases reviewed, 85% are combined with stone masonry, detected in 78% of these cases. In addition, fewer instances are observed of earlier configurations with pebbles and small pebbles, as well as flat stone and slabs, present in 6% and 5% of cases, respectively. Coexistence with other techniques such as ceramic brick, whose use became widespread from the start of the 1st century BC (Pastor, 2017), is observed especially in later sites, accounting for 17% of the current cases documented. This is especially used for plinths, as in the case of El Molinete.

6. Conclusions

The dispersed pattern of cases confirms the geological and climatic suitability for the development of historic earthen constructions in the Iberian Peninsula, with the exception of areas affected by particularly heavy rainfall. Despite its complex origins, the material has evolved in step with the references consulted. The architectural data cover a wide range of structures and elements adapted to the different needs and provide extensive detailed information relating to the Iberian Peninsula.

In technical terms, the wide variability of applications is a response to numerous internal and external factors. Cob has mostly been lost, except in flooring. In the periods studied more in depth adobe is the main solution, with multiple applications and a wide range of sizes, albeit with frequent lengths and heights, around 40 and 8-10 cm respectively, or with widths of 20-30 cm which gradually increased towards the Roman period. The use of rammed earth became more prominent at this stage, with frequent cases measuring between 50-80 cm. Thanks to the in-depth study of the most vulnerable cases basic documentation can be established for use in risk analysis.

References

Abad, L., & Sala, F. (1993). *El poblado ibérico de El Oral (San Fulgencio, Alicante).* Diputación Provincial de Valencia.

Aranda, G., & Molina, F. (2005). Intervenciones arqueológicas en el yacimiento de la edad de bronce del Cerro de la Encina (Monachil, Granada). *Trabajos de prehistoria, 62*, 165-179.

Arenas, P., Carrasco, I., Conlin, E., et al. (2003). Intervención arqueológica en el patio de San Laureano de Sevilla. *Anuario Arqueológico de Andalucía, 3*, 239-255.

Arribas, A., Pareja, E., Molina, F., Areaga, O., & Molina, F. (1974). *Excavaciones en el poblado de la Edad de Bronce Cerro de la Encina. .* Servicio de Publicaciones del Ministerio de Educación y Ciencia.

Asensio, J. A. (1995). Arquitectura de tierra y madera en la protohistoria del Valle Medio del Ebro y su relación con la del Mediterráneo. En M. Beltrán Lloris, *Caesaraugusta, nº 71* (págs. 23-56). Institución Fernando el Católico.

Azuar, R., Rouillard, P., Gailledrat, E., et al. (1998). El asentamiento orientalizante e ibérico antiguo de "La Rábita", Guardamar del Segura (Alicante). *Trabajos de prehistoria, 2*, 111-126.

Belarte, M. C. (2011). L'utilisation de la brique crue dans la Péninsule Ibérique durant la protohistoire et la période romaine. En Chazelles, C.A.; Klein, A.; Pousthomis, N. (2011). *Les cultures constructives de la brique crue. Echanges transdisciplinaires sur les constructions en terre crue,* 3. Éditions de l'Espérou.

Chazelles, C. A. (1990). Les constructions en terre crue d'Empúries à l'époque romaine. *CYPSELA, VIII*, 101-118.

Chazelles, C. A. (1995). Les origines de la construction en adobe en Extrême-Occidente. Sur les pas des grecs en Occident. *Études Massaliottes, nº 4*, 49-58.

Chazelles, C. A. (1997). *Les maisons en terre de la Gaule méridionale.* Monographies instrumentum, 2.

Chazelles, C. A., & Poupet, P. (1985). La fouille des structures de terre crue: définition et difficultés. *Aquitania, 3*, 149-160.

Font, F., & Hidalgo, P. (1990). *El tapial: una tècnica constructiva mil·lenaria.* COAAT Castellón.

Jover, F. J., Pastor, M., Basso, R. E., et al. (2019). Secuencia de ocupación y desarrollo constructivo del asentamiento de Caramoro I (Elche, Alicante): aportaciones a la arquitectura argárica. *Arqueología de la arquitectura, 16*, 1-24.

Luzón, J. M. (1973). *Excavaciones en Itálica: estratigrafía en el Pajar de Artillo.* Servicio de Publicaciones Ministerio de Educación y Ciencia.

Matero, F. (2013). Making Archaeological Sites: Conservation as Interpretation of an Excavated Past (2006). Getty Publications.

Moret, P. (2001). El Tossal Montañés (Valdeltormo, Teruel): une maison-tour ibérique du VIe siècle av. J.-C. *Madrider Mitteilungen, 42*, 85-101.

Navarro, J., & Jiménez, P. (2011). Materiales y técnicas constructivas en la Murcia andalusí (siglos X-XIII). *Arqueología de la arquitectura, 8*, 85-120.

Pastor, M. (2017). *La construcción con tierra en arqueología: teoría, método, técnicas y aplicación.* Universidad de Alicante.

Plasencia, F. J. (2016). *Bòbila Madurell-Mas Duran: Formas de vida en el Neolítico medio y final de nordeste peninsular.* Universitat Autònoma de Barcelona.

Rouillard, P., Gailledrat, E., & Sala, F. (2007). *L'établissement protohistorique de La Fonteta (fin VIIIe - fin VIe siècle av. J.-C.).* Casa de Velázquez.

Sánchez, Á. (1999). Las técnicas constructivas con tierra en la arqueología prerromana del país valenciano. *Quaderns de Prehistòria i Arqueologia de Castelló, 20*, 161-188.