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Literature review on earthen vernacular heritage: contributions to a referential framework

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Abstract

The state of the art of earthen architecture and vernacular built heritage comprises a complex set of issues that range from fundamental problematic recognition to anthropological and cultural studies and, more recently, to technological and experimental analyses. This paper addresses the development of the field, following the milestones of the international literature and pursuing a reflective-theory approach within a historical framework. It aims to explore the main contributions that have enhanced vernacular heritage and earthen architecture as specific domains, from pioneering public awareness essays to institutional expertise guidelines. Finally, in addition to the literature review process, this paper considers the recent corpus of recommendations from conservation management reference institutions, the updating of the operative problematic of earthen vernacular built heritage, and the relevance of local community involvement in facing increasing challenges.

Keywords Vernacular heritage, Earthen architecture, Conservation

1 Introduction

This paper addresses the state of the art of earthen vernacular architecture with the objective of establishing a general theoretical framework and promoting an extended focus on specific research challenges.

Considering the geographical diversity of the topic, this paper addresses the international milestones of published studies on earthen built heritage. Therefore, the draft is organised into five major conceptual categories that expose the historical progression of the theme, which can be summarised as follows:

1. The definition and evolution of earthen vernacular architecture scientific research
2. The consolidation of the sample
3. Advances in the technical characterisation of earthen materials and systems
4. Protection of the earthen built environment
5. Earthen architectural heritage conservation

This paper applies a reflective-theory methodology approach to a conventional literature review, creating a progressive illustration that extends from ethnographic studies that highlight vernacular earthen architecture to technological and the most recent experimental studies.

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2 The definition and evolution of earthen vernacular architecture scientific research

> *There is much to learn from architecture before it became an expert's art. The untutored builders in space and time – the protagonist of this show – demonstrate an admirable talent for fitting their buildings into the natural surroundings. Instead of trying to 'conquer' nature, as we do, they welcome the vagaries of climate and the challenge of topography. (Rudofsky 1990, 5)*

The early literature on earthen architecture is associated mainly with traditional and vernacular architectural essays. Even in recent papers, such as those that constitute the current issue of the *Built Heritage* Journal, it is quite usual to refer to the pioneering contributions of names such as Sibyl Moholy-Nagy, Bernard Rudofsky, Hassan Fathy, and Paul Oliver to establish the first milestones. Although there are questions regarding these scholars' scientific structures, the impact of their work was so overwhelming that they are still considered key figures in the development of the subject (Dethier 2019).

According to a significant number of interpretations, these contributions are supported more by their critical approach to the subject than by the subject development itself. In the 1960s, the Western world, due largely to the exhaustion of modern movements, saw a return to the study of the meaning of traditional forms that characterised the diversity of regional architecture. Rapoport (Frey 2010) deepened his studies, establishing the term vernacular architecture in 1968. Rudofsky had already provided a global dimension in the famous 'Architecture without Architects' exhibition at the Museum of Modern Art (MoMA) in 1964.

Based on ethnographic perspectives, scholars began to focus on the specific built environments of indigenous communities, decoding the cultural ties between their local needs and their architectural solutions, breaking ground for the evolution of a concept of cultural identity. Therefore, these references must be perceived outside a simple morphologic-typological inventory, as they are often considered works of dissemination and promotion with subsequent influence beyond their contexts and generation (Asquith and Vellinga 2006).

Despite the years that separate them and the methodological differences that configure them, these contributions, with all their strengths and weaknesses, set the bases and the conceptual parameters for present-day definitions of terms (Carlos et al. 2015).

The first approach to regional architecture began, naturally, through the first ethnographic essays, initially in the form of monographs dedicated exclusively to small rural settlements with which the authors shared some relationship or affinity. The origin of this field was generated by the increase in the social, cultural, and anthropological sciences from the beginning of the 20th century. With the consequent development of ethnography and human geography, housing, especially traditional forms, came to constitute a valuable aspect of the understanding of communities and their cultural evolution. In the early stage, scholars might have been interested primarily in the most exotic and culturally contrasting civilisations, whereas later, the internal reality of European countries also began to attract interest. Albert Demageon, an unavoidable figure of the social sciences, revealed a new dimension from the 1920s onwards (Oliver 2003). An understanding of his approach could be understood as mandatory for any study that aims to comprehend the matrix of the cultural identity phenomenon of each nation, an exacerbated interrogation in Europe troubled by the Great World Wars.

With the deepening of such analyses, construction companies began to request the participation of stakeholders in construction areas. The simple enunciation of processes through popular accounts and local artisans was possible, but the systematisation, registration, and classification of those processes required knowledge and competence. This led to the effective involvement of architects with knowledge of popular architecture, although as supporting agents.

Another determining factor was the consolidation of the 'antihistorical' gap in the intellectual process of architecture dictated by the radiant rationalist movement in instances of the international panorama. It is true that relevant antecedents already existed, such as a first reaction, by Ruskin (1851) as an alternative to the dominance of the neoclassicism of the 19th century. Despite never having imposed itself on its ideological adversary, the Arts and Crafts picturesque perspective continued to captivate and stimulate architects over time, although without massive influence, leading to closer observation of the vernacular legacy. The same legacy, ironically, would become a valid alternative in the announcement of the exhaustion of rationalism itself within its antihistoricist logic. The vernacular legacy began to emerge as a critical reaction to what was considered the dehumanisation of the international style, especially around the mid-20th century. References can be found in the works of those who, like Alvar Aalto, never abstracted from the physical and cultural reality into which they inserted their works and later recognised in Norberg-Schulz's premised valid themes for experimenting with a theoretical reformulation (Rapoport 1972).

Also important was the alienation of European nations, which in the ravaged aftermath of the war imposed political resistance and ideologies on anything foreign.

The recognition and validation of political power, even for the wrong reasons, would turn out to be fundamental for the involvement of architects in the study of regional architecture. This involvement would lead to a claim of responsibility for the exclusive execution of surveys of regional architecture before those in political power assimilated the values of national traditions. In a restricted professional cycle, and given the necessary changes and growth in training academics, these professionals would be responsible for the emergence of a theoretical awareness of the intellectual environment. At a later stage, this theoretical development would stimulate repercussions and adherence in the main academic centres through the restructuring of their pedagogical curricula, especially with the inclusion of the ethnography discipline in their courses (Frey 2010).

The development of the earthen vernacular heritage literature was a direct consequence of the extension of the earthen architecture characterisation, which was strongly based on the implementation of regional inventory surveys. These recorded technical descriptions, more than an operative objective for the perpetuation of the building culture, were the premise of a collective memory in the face of the decay of the traditional rural economy, which was exponentially felt in industrial countries in the second half of the 20th century (Asquith and Vellinga 2006).

Surprisingly, or perhaps unsurprisingly, this conceptual approach questioning the essence and future of vernacular architecture, in which earthen architecture plays a significant part (Houben and Guillaud 1995), is still a relevant branch of the actual literature. This is widely explained by the ineffectiveness of previous awareness documents and actions, especially in the context of national conservation and protection politics (Avrami, Guillaud, and Hardy 2008).

3 The consolidation of the sample

> *A modern select bibliography of earth construction would comprise more than 10,000 titles. Most of these are difficult, if not impossible, to obtain. The bibliography given here covers only the most important works, which are obtainable through normal commercial channels.*
> *(Houben and Guillaud 1989, 359)*

The above passage from the revised edition of *Earth Construction: A comprehensive guide*, published in 1989, reflects the ambition of a literature review on the subject. As can be inferred from the findings of this paper, the limitations of this intention would increase exponentially, especially at the turn of the millennium, due to the high number and great diversity of contributions.

Any contemporary effort to present the state of the art of earthen architecture must be understood as a highly contextualised and interpretative exercise profoundly conditioned by the document language, as the stated references confirm. The proposed bibliography is organised by language: English, French, German, Italian, Portuguese, and Spanish.

It is precisely the references constituting what can be interpreted as 'the consolidation of the sample' that contribute to the increase in the research. Despite being framed thematically and chronologically, they represent a significant percentage of recent and actual research and extend the spectrum of approaches to different research problems (Avrami, Guillaud, and Hardy 2008).

It is possible to establish that the original focus of most studies was the identification of built heritage assets and a report on their state of conservation. Validated as regional surveys, these studies are usually driven by national administrative directives or academic proposals and are expected, in the long term, to contribute to the documentation on which eventual protective plans and actions are based.

The previously mentioned ethnographic studies from the mid-20th century represent pioneer records using Albert Demageon's previous work about rural territories and their particular relation with human habitats. Most of these early studies were related to regional internal mobilisations established by national ideologies; the scholars investigated social differentiation and considered the vernacular built environment to be an identity component (Scalesse 1980).

Auzelle's systematisation approach to architectural/urban elements constitutes the main operative complement, especially in the implementation of graphical documentation in architectural surveys. Although regional construction manuals existed in Europe as early as the 18th century (Rauch 2014), the period between the 19th and 20th centuries is rich in inventories addressing the vernacular architecture, building systems, and characteristic techniques of specific regions and published in local languages, which constrained their international impact. From this universe of production, it is possible to confirm the substantial development of publications dedicated to rammed-earth and adobe masonry construction and buildings. Houben and Guillaud's publication in French and English (Houben and Guillaud 1995) is a special reference in the area.

The temporal extension of vernacular architecture occurred for two major reasons:

1- The late value recognition of vernacular buildings, conforming to unbalanced maps of heritage interest and
2- The intrinsic characteristics of rural areas, which dominate earthen heritage locations, especially remote and less populated ones, tend to be denounced by the main cultural heritage policies and operative investments (Frey 2010).

The inventory format was widely developed and published during the last decade of the 20th century, and the report file was used as the preferred documentation systematisation tool. This approach marked institutional engagement in the field and the interest of academics, opening the subject to a range of scientific exercises. This opening was decisive for the beginning of various graduate research investigations, such as master's dissertations (e.g., Correia 2007a) and Ph.D. theses (e.g., Ribeiro 2021). For example, since the 1980s, the master's degrees developed at CRAterre have had a major influence.

Progressively, this category has been converging to a more collective dynamic. More recently, individual contributions have been replaced by institutional initiatives through the formats of research project publications (Correia, Dipasquale, and Mecca 2011), proceedings of seminars and conferences (Correia, Carlos, and Rocha 2014; Correia, Dipasquale, and Mecca 2014; Mileto et al. 2018), publications based on network activities (Correia et al. 2016a, b; Correia, Guerrero, and Crosby 2016) and research (Dipasquale, Correia, and Mecca 2020).

The literature produced in the past decade indicates that worldwide, earthen vernacular architecture has become a subject of unquestionably great interest, especially when literature produced during this decade is compared with literature produced in preceding decades. The earthen vernacular architecture literature in this period has grown considerably in quantity and quality. Four main aspects characterise the scientific production in this area: the typology of the contributions, the countries involved, the content, and the trends.

The typology of the contributions has been implemented with an ever-increasing number of proceedings of conferences dedicated to earthen architecture. During the analysed time frame, several books were published that collected contributions from conferences and congresses (such as TERRA conferences and congresses, ISCEAH and CIAV conferences, LEHM conferences, and VERSUS and RESTAPIA conferences) that focused on earthen architecture but related the subject area to other key areas of interest: from conservation to vernacular architecture and from specific techniques to issues of risk assessment, testifying to the interdisciplinarity that connects earthen architecture with other research areas. This interdisciplinarity can be observed in the proceedings of international conferences held in Mali in 2008 (Rainer, Rivera, and Gandreau 2011), Peru in 2012 (Correia et al. 2016a, b; Correia, Guerrero, and Crosby 2016), and France in 2016 (Joffroy, Guillaud, and Sadozaï 2017), among others. Additionally, several other international conferences were organised by different academic institutions with the support of the ICOMOS Scientific Committee on Earthen Architectural Heritage (ISCEAH) together with other ISCs, such as the Vernacular Architecture International Committee (CIAV). The result is an extraordinarily rich collection of contributions that offer a very detailed overview of specific research and related subject areas (Hwang, Guillaud, and Gandreau 2011; Dachverband Lehm e.V. 2012; Mileto, Vegas, and Cristini 2012; Correia, Carlos, and Rocha 2014; Correia, Dipasquale, and Mecca 2014; Mileto et al. 2015; LEHM 2016 conference; Mileto et al. 2018; Shao, Jakhelln, and Correia 2019).

A new typology of publication that appears in the framework and should be mentioned is the publication of data from international projects. Among this group of publications, books edited as a result of the Lessons from Vernacular Heritage for Sustainable Architecture (VerSus) project (2014–2016) (Correia, Dipasquale, and Mecca 2011; Correia, Carlos, and Rocha 2014; Correia, Dipasquale, and Mecca 2014); the Living and Visiting European Vernacular World Heritage (3DPAST) project (Dipasquale, Correia, and Mecca 2020); the Coremans Spanish research project (Mileto and Vegas 2017) RESTAPIA, dealing with the conservation and restoration of historical rammed-earth heritage (Mileto et al. 2018); and the SEISMIC-V: Earthquake-Resistant Vernacular Culture in Portugal project developed under the National Foundation for Science and Technology in Portugal (Correia, Lourenço, and Varum 2015) should be highlighted. Other project results were published in Italy, France, Germany, Greece, and other countries. These projects were publicly funded following highly competitive contests, and, as a direct result, the publications were freely available online. This is very important, as books, especially conference proceedings, are often very expensive and consequently not widely disseminated in an area that usually has less funding than other fields.

Notably, in recent years, online publications have increasingly circulated, spreading knowledge more rapidly and broadly and increasing the dissemination of research on earthen vernacular architecture. Publications in regions other than Europe, such as China (Shao, Jakhelln, and Correia 2019), Latin America (Correia et al. 2016a, b; Correia, Guerrero, and Crosby 2016), and Arab countries (Pradines 2018), are now also a reality. It is the case in. These contributions are often written only in

national languages and therefore are not widely accessible, but it is important to register the significant recent increase in activity in such publications. Additionally, there has been an effort to publish in English to increase the dissemination.

The research area is evolving from merely descriptive to interdisciplinary, analytical, and even critical approaches. Contributions that in the past focused mainly on local building cultures and more general research areas related mainly to quality, single building techniques, and material characteristics have developed into a more articulated and enriched research area that incorporates studies on building sustainability (e.g., VERSUS project) and digitalisation (e.g., 3DPAST project).

Foreseeing the potential of gathering field specialists and converging aims and goals on the stated problems in a more consolidated approach, the Mediterra 2009: 1st Mediterranean Conference on Earth Architecture was an important milestone for a supranational study on earthen architecture (Achenza, Correia, and Guillaud 2009). Based on several preliminary research activities, Mediterra 2009 extended the target audience beyond experts and academics and focused on political and administrative agents, aspiring to a more operative result of the protection and conservation of the related heritage (Achenza et al. 2006). At a European level, this is reflected by the Terra (In)cognita projects and the subsequent related publications, which are an example of an attempt to establish an overall state of the art of traditional earthen building techniques in Europe (in Terra Incognita I) and of earthen architecture in the European Union (in Terra Incognita II).

Earthen vernacular architecture has expanded into new fields of interest and highly specialised subjects related to history and conservation. The aim is to acquire better energy efficiency in historical buildings and to suggest an adequate level of transformation to satisfy the new comfort requirements. Therefore, many contributions are focusing on the industrialisation of processes (productive and constructive) and general performance improvements in traditional materials and techniques. Many contributions are also concentrating on the conjunction of earth/sustainability and discussing different levels, including global, of concerns about climate change, natural risk assessments, and, more recently, the pandemic.

Finally, it is important to note that the theme of the global digitalisation process has been introduced into many scientific papers that focus on new approaches to the documentation of the built environment: 3D data, GIS, BIM, HBIM, and laser scanning are tools commonly used to map and acquire digitalised data concerning earthen heritage (Campiani, Lingle, and Lercari 2019; Lercari 2019; Achenza and Cocco 2015). This type of contribution will elevate proceedings, chapters, and articles as the most usual information format, validating their scientific rigor and reinforcing the disciplinary autonomy of the field, which will be the determinant of the next step. On the other hand, the stated format has also contributed to the fragmentation of information sources, minimising the impact of their contribution despite their quality and creating overqualified circles with little interdisciplinary interest (Bendakir 2009).

4 Advances in the technical characterisation of earthen materials and systems

'Earthen Construction: A comprehensive guide' (1994), originally published in 1989 as *Traité de construction en terre* from CRATerre, is consensually considered a turning point in the contemporary approach to earthen material and technology research. Comprising a set of previously published pedagogical materials to complement the CRATerre-EAG specific formations, the publication was collected and developed by Hugo Houben and Hubert Guillaud. It constitutes a technical synthesis of didactic purposes, of simple and objective communication. It is framed within a paradigm change that aimed to establish scientific validation for earthen material characterisation, refuting the exclusively empirical dimension of previous documents and clearly motived by the generic technological prejudice against traditional materials and techniques that was internationally apparent during the second half of the 20th century.

To confirm its authority in the field, it can be compared with more recent examples, such as Laurence Keefe's (2005) work, which seems to follow the same orientation, revealing an overall structure very similar to the earliest CRAterre documents. In this case, the development of issues concerning technical conservation in particular, with an important contribution regarding the identification of failure, constitutes the final chapters of the publication. Another transition in this work is the methodological and scientific rigor of the contents,

This category, widely enhanced by the breakthrough in experimental studies in the 2000s, has been justified by two main circumstantial objectives: 1- to develop compatible construction solutions for interventions in traditional earthen buildings, namely, preserving their physical identity, and 2- to consider more eco-friendly alternatives to high-carbon construction materials. The two objectives are commonly grouped under the purpose of understanding their potential/conflict within the actual construction parameters and are regularly presented in a comparative approach to industrial production materials and composites, namely, concrete.

In recent years, researchers and professionals, motivated by the recognised lack of information, have

compiled information on the mechanical properties of earth materials and the structural behaviour of earthen structures. This type of structure presents important fragilities that can endanger its structural behaviour and its inhabitants. Earthen structures generally present a low compression strength and a brittle behaviour in tension and shear. In addition, earthen structures frequently have an inadequate foundation, geometric irregularities, and ineffective connections between walls and floor or roof components. The typical high mass of these structures may generate important inertia forces under seismic action, which, in combination with the material and structural properties, may result in deficient seismic behaviours (Minke 2003; Miccoli, Mueller, and Fontana 2014).

Earth properties vary from place to place; therefore, the mechanical properties of earthen structures will vary accordingly to the location of materials extraction. Mechanical material characterisation has been conducted in different countries on the basis of traditional materials and local construction techniques and methods. The lack of consolidated standard testing procedures has created difficulties in comparing the test results obtained with different materials, specimen preparation procedures, construction techniques, and methodologies of different regions. Varum et al. (2021) present a collection of experimental and numerical developments related to the structural characterisation and seismic retrofitting of adobe. A compendium of national and international normative documents and standards can be found in Silveira et al. (2021). For example, for adobe characterisation, there is strong variability in the test procedures concerning specimen size, treatment of specimens before testing, platen restraint, application of correction factors, type of test rate (strength or velocity), admissible limit values, etc. Nevertheless, important research has been conducted on the material and its monolithic and masonry characterisation, using material from existing constructions or manufacturing it using traditional methods. Representative values of compressive strength, strain at peak stress, modulus of elasticity, Poisson ratio, and other factors for adobe testing conducted in different countries are provided in Silveira et al. (2021). Additionally, adobe masonry values for aspect ratio, compressive strength, tensile strength, mortar properties, deformations registered, modulus of elasticity, and Poisson ratios are compiled in Oliveira et al. (2021).

Asprone et al. (2016) tested single-leaf adobe wallets, Silveira et al. (2015) performed experimental tests with five full-scale adobe panels, Miccoli et al. (2015) produced and tested earth block masonry panels, Vargas-Neumann (1993) conducted a parametric study for rammed-earth walls, and Bui et al. (2008) studied a rammed-earth load-bearing wall and compressed earth blocks (CEBs), among many other studies of earthen structures. The composition of the soil, additives used (straw, fibres, etc.), mortar employed, conservation state, level of damage, and exposition time play important roles in the results. However, with the experimental tests, stress-strain curves of the material are obtained, which leads to designing constitutive equations to be used in numerical modelling. Moreover, failure modes are identified, which allows the specification of more effective structural rehabilitation, retrofitting, and strengthening strategies.

There are many examples of the use of different reinforcement solutions adopted in practice since prehistoric times, for instance, in Peru, an earthquake-prone country (Varum et al. 2021). More recently, different studies have characterised the efficiency of those solutions. As earthen structures are very popular in many low-income regions, specific research has been conducted to identify low-cost and low-tech strengthening techniques (Dowling and Samali 2009; Tolles 2009). Internal strengthening systems, using, for example, grout injections or bed-joint reinforcement, can improve the behaviour of masonry panels. External strengthening systems, in addition to improving the mechanical properties of the structural components, allow the bonding of those components, improving the overall structural behaviour. The literature provides examples of this type of strengthening using rope and cane-rope grid systems, timber caging, ferrocement-like strengthening systems, steel tensioners, synthetic and natural polymer grids, and car tire straps (Parisi et al. 2021; Blondet and Aguillar 2007).

Nevertheless, despite the extensive research already conducted, further research is needed to support the definition, design, and detailing of solutions that may allow the existing earthen heritage to be adequately preserved. Additionally, it is relevant to underline the few processes of comprehensive literature reviews that have been undertaken. For example, the 'Terra Literature Review: An Overview of Research in Earthen Architecture Conservation' (Avrami, Guillaud, and Hardy 2008) was a complement to the GAIA project, which consisted of an exception in the international panorama.

5 Protection of the earthen built environment

When approached as an objective, this category can be interpreted as a transversal concern, since the bottom-line common purpose is to endorse the perpetuation of this traditional built culture. Awareness of the technological specificity of earthen construction and its traditional features within a specific cultural context is a significant part of the literature. Although this trend of

contributions is chronologically irregular and has had diverse impacts, it has been maturing alongside the cultural heritage concept and its specific technical components. A good example is Dethier's 'Habiter la terre. L'art de bâtir en terre crue' (2019), which proclaimed the need to protect not only examples of international value recognition and their techniques and procedures but also their technological evolution into present valid solutions.

Nevertheless, most of the literature is not so ambitious and merely addresses a geographical contextualisation of a specific recognisable heritage-built asset, correlating the earthen built environment with its exceptional attributes. This condition, when coincident with UNESCO World Heritage sites, can be easily traced with the outstanding universal value interpretation. This can be confirmed by the broad extension of studies of buildings such as the Great Mosque of Djenné or the Fujian tulous, to name only some of the most emblematic and recognisable earthen constructions (Correia et al. 2016a, b; Correia, Guerrero, and Crosby 2016; Joffroy 2012; Jaquin, Augarde, and Gerrard 2008). This type of information currently constitutes more than 70% of earthen heritage data sources.

The increased number of earthen properties listed as World Heritage in recent years contributes to the dissemination of knowledge about such sites and is important for their protection. There are 161 earthen heritage sites classified by UNESCO (last updated in 2019), which represent 14% of the World Heritage List (UNESCO 2020; Joffroy 2012). Granting earthen architectural heritage universal value is not only an acknowledgement of its importance as historical evidence but also a way of engaging local communities in the relevance of their heritage as a cultural legacy. With this in mind, the important role of local communities in the protection and preservation of built heritage is a subject that has attracted the attention of international committees in recent years. The World Heritage Convention (in 2002) defined five strategic objectives to be developed and implemented in the long term, known as the 5 C's. The last 'C' was added later (in 2007), and it stands for 'Community', referring to the aim of engaging local communities in the process of decision-making in a conservation project. This aspect was later reiterated by the Kyoto Vision (2012), which stated that communities, in particular, should be empowered to harness the benefits of heritage to society through specific awareness-raising initiatives, skills-development programs, and the establishment of networks. They should be fully involved in management and conservation activities, including reducing risks associated with disasters and climate change (UNESCO 2012).

Vernacular heritage, and particularly earthen vernacular buildings, has a strict connection with local communities. As stated in the *Charter on the Built Vernacular Heritage* (1999), the appreciation and successful protection of the vernacular heritage depend on the involvement and support of the community, continuing use, and maintenance (ICOMOS 1999). Owing to awareness of this important bond between local people and earthen buildings, an important conference entitled 'The Conservation of Decorated Surfaces on Earthen Architecture' was organised by the Getty Conservation Institute in 2004. The main focus was on not only the preservation of materials and decorative techniques but also the continuity of know-how and traditions (Rainer and Rivera 2006).

However, despite the relevance of communities in the protection of earthen architecture, the body of literature related to this research area was scarce until recent years. In most cases, it was specific to a particular heritage site (e.g., CERKAS and GCI 2016; Bertagnin and Sidi 2014). The connection of local people and earthen buildings is one of the many characteristics of this type of heritage. It is also one of the distinctive factors when earthen heritage is compared to the other types of monuments and buildings. International committee should give special emphasis to this issue so that specific guidelines can be drawn to develop a holistic methodology within the conservation framework.

Some authors have invested in more operative studies in efforts to develop explicit contributions to the field of earthen architecture conservation. In this group, the main effort is to justify the particularity of the field, which is strongly marked by its intrinsic material vulnerability and rapid loss of knowledge transmission. Initiatives for collecting traditional practices related to construction techniques have been one of the main sources of studies on earthen vernacular construction. From the earlier publications and systematisation of information performed by CRAterre (Houben and Guillaud 1995) to more recent data collection, such as the Terra Europae book (Correia, Dipasquale, and Mecca 2011), the Versus project (Correia, Carlos, and Rocha 2014; Correia, Dipasquale, and Mecca 2014), and the Coremans project (Mileto and Vegas 2017). In addition to construction techniques, other authors have developed a different line of research, focusing on products and materials used for the protection and conservation of earthen heritage (Joffroy 2005; Checa and Cristini 2012; Correia 2016; Vissac et al. 2017). This expertise is of extreme importance in the context of earthen vernacular architecture preservation and is outlined through its unique characteristics. The conservation community should pay more attention to this approach.

6 Earthen building heritage conservation

Finally, in what is specifically regarded as the conservation of earthen architectural heritage, two main knowledge gaps can be detected in the literature—the lack of conservation theory as a background for earthen heritage interventions and the need for a clear understanding of the values and significance of a place. These two interlocking aspects contribute immensely to less conscious conservation actions and the implementation of methodologies that do not follow the basic principles of heritage intervention.

Consequently, common failures in earthen architecture conservation can be attributed to the lack of a conservation theory framework. Even though the subject of earthen heritage conservation has been addressed broadly in the literature, the main focus has not yet been on conservation theory. The main highlighted research themes are commonly related to practices and methods. As a result, few publications about conservation theory (Warren 1993, 1999; ICOMOS 1999; López-Manzanares and Mileto 2001; Correia 2016), as well as few papers (Jokilehto 2003; Correia and Fernandes 2006; Correia 2007b), can be cited.

The importance of applying conservation theory to the particularities of each heritage field intervention was mentioned by Feilden and Jokilehto (1998). Additionally, Brock-Nannestad (2000) described conservation theory as a well-founded action regarding the survival of the physical entity for present and future visitors. Problems such as authenticity before and after treatment must be handled in such a way that the professionals who are responsible for decision-making and for carrying out the decisions may feel assured that they have managed these matters conscientiously and responsibly. As Brock-Nannestad (2000), 22 mentioned, there must be no doubt of the consequences of an action (or its omission).

In parallel, the assessment of the heritage value and significance of a place can guide decision-making since it defines priorities of intervention and respects all tangible and intangible features. A building or monument should be observed from an overall perspective, where not only the physical state but also incorporating a widespread understanding of all conditions that make that place unique is the main priority, embodying all conservation principles. The assessment of significance in earthen architecture has been addressed in the literature by a few authors (e.g., Correia and Walliman 2014; Correia 2016; Mileto and Vegas 2017) but still requires more awareness and development from the conservation community.

In the last 20 years, the creation of committees such as ISCEAH-ICOMOS and international programmes, such as WHEAP from UNESCO, has demonstrated the impact of earthen heritage on a global scale and the efforts that have been made to promote, create awareness of, and protect earthen architecture. However, specific regulations have still not been produced, and such an effort is crucial not only to adopt a strategic plan for earthen heritage sites but also to generate more homogeneous concepts of intervention criteria. As Correia stated: *A thorough literature review confirms that earthen architecture did not have specific Charters, norms, principles, documents, nor international recommendations developed by ICOMOS or UNESCO. There are only recommendations produced at the end of each Terra conference. Therefore,*

Table 1 Summary of research areas related to earthen heritage conservation addressed in the last three Terra conferences

Year, Country	Conference	Research areas (within the theme conservation) – number of lectures
2008, Mali	Terra 2008 10th International Conference on the Study and Conservation of Earthen Architectural Heritage (Total of 64 lectures)	Assessment of values and significance – 3 Management, monitoring, and conservation planning – 7 Documentation – 3 Review – 1 Materials characterisation and innovation – 11 Interventions (case studies) – 6 Total – 31 lectures
2012, Peru	Terra 2012 (SIACOT) 11th International Conference on the Study and Conservation of Earthen Architectural Heritage (Total of 49 lectures)	Preventive conservation – 1 Management, monitoring, and conservation planning – 6 Documentation – 2 Review – 1 Materials characterisation and innovation – 7 Interventions (case studies) – 4 Total – 21 lectures
2016, France	Terra 2016 12th World Congress on Earthen Architecture (Total of 57 lectures)	Management, monitoring, and conservation planning – 4 Review – 1 Materials characterisation and innovation – 10 Interventions (case studies) – 5 Total – 20 lectures

there is a need for further research in order to suggest specific recommendations for the preservation of earthen architectural heritage (Correia 2016, 88).

The Terra conferences started in 1972 with the 1st International Conference on the Conservation of 'Mud-brick' (Adobe) Monuments, held in Yazd, Iran (Correia 2016). Since then, eleven more conferences have been held in different countries. These conferences are organised under the aegis of ISCEAH-ICOMOS, and depending on the country, different partners are involved. Specifically, regarding the last three Terra conferences – Terra 2008, held in Bamako (Mali); Terra 2012, held in Lima (Peru); and Terra 2016, held in Lyon (France) – interesting conclusions can be drawn about the number of lecture topics and the evolution of subjects and themes (Joffroy, Guillaud, and Sadozaï 2017; Correia et al. 2012; Rainer, Rivera, and Gandreau 2011). Table 1 shows the number and typology of research areas.

The results of the three selected conferences show that the number of lectures on the conservation topic was reduced. This may be due to a greater focus on topics and themes such as local knowledge, intangible values, new earthen architecture, education and training, and standards and guidelines. Materials characterisation and innovation is the topic with a higher number of lectures, which is not surprising since it is the most developed research related to earthen construction due to higher involvement of engineering and material sciences scholars in recent years. In this quantitative analysis, topic was labelled 'interventions (case studies)' only when the authors mentioned a specific earthen heritage site and the steps of the associated conservation intervention (with indications of methods, products, and procedures).

Considering this analysis, the recommendations and dissemination of scientific work presented in the Terra conferences are not enough for the implementation of global guidelines for the conservation of earthen buildings. Nevertheless, the principles and ethics already established in the existing charters and regulations can (and should) be applied to earthen conservation projects. It is also evident that there has been an evolution, from the Athens and Venice charters to the present day, of concepts and notions of what is heritage, the diversity of cultural aspects that surround it, tangible and intangible values, the importance of preservation and maintenance, and the involvement of the community as well as the review of conservation principles such as compatibility, reversibility, authenticity, integrity, unity, and minimum intervention.

In a recent conference held in Florence in 2018 by ICOMOS entitled 'Conservation Ethics Today' (Schädler-Saub and Szmygin 2019), several interesting new approaches to conservation practices and principles were addressed, namely, the meaning of ethics in the conservation and restoration of heritage today; the importance of interdisciplinary cooperation in the field of heritage; present-day values: use-value, artistic and newness values, and social values; and the abandonment of the typical Eurocentric position in perceptions and preservation of cultural heritage in favour of a broader view of diverse meanings and traditions of conservation and restoration in other parts of the world. This updated vision of current conservation values and principles represents the most recent guideline, which can also be used as a referential framework for earthen heritage.

Another important step regarding the conservation of earthen heritage is the uniformisation of the terminology. In the literature of case studies, there is generally an identification of the main factors that contribute to earthen material degradation, but the deterioration patterns are usually too general. Sometimes, when presenting decay phenomena, there is a misunderstanding of factors and pathologies. Terms such as damage (Mileto and Vegas 2017), degradation and dirt (Vegas, Mileto, and Cristini 2014), weakness, loss of bonding, alterations (Rocha 2012), vulnerability (Bertagnin and De Antoni 2012), surface loss, stains (Graciani et al. 2012), parasite vegetation (Orihuela and Castillo-Martínez 2012), and exfoliation and cracking (Li et al. 2011) are examples of a lack of homogeneity in identifying decay phenomena. Additionally, the descriptions tend to be too vague and brief, drawing more attention to materials characterisation and the intervention itself.

ICOMOS-ISCEAH recently published a glossary of earthen material deterioration patterns (ISCEAH 2021). This important document reveals how the scientific approach to earthen heritage conservation has been developing and responds to the need to harmonise degradation terms related to this research area. Before the ICOMOS-ISCEAH glossary, glossaries were developed by CRATerre, GCI, ICCROM, and UNESCO, but only for specific interventions in earthen heritage sites. There is also an online glossary for earthen architecture terminology, but the terms are used mainly for different areas of earthen construction (Dachverband Lehm e.V n.d.). Since this glossary is very recent, there are still no references to the use of this tool in the literature. Therefore, some authors have proposed filling out a form to describe sources and causes of current damage and dividing pathologies into groups – material, structural, surface damage, atmospheric agents, and anthropic (Canivell 2012; Mileto, Vegas, and Cristini 2012).

The importance of a common and shared language to describe the typologies of degradation mechanisms specific to earthen heritage is shown by the fact that its absence has resulted in scarce initial characterisations that can lead to the misinterpretation of real decay phenomena. Consequently, treatments and products can be used incorrectly, or sometimes used excessively, when preventive measurements could have been enough.

7 Conclusions

The area of heritage conservation in earthen architecture constitutes a broad and heterogeneous body of knowledge whose specificity paradoxically contrasts with the antiquity of such practices.

Essays on the categorisation of associated contributions are still limited when considering the extent of the volume of work on the topic. Of these, excluding the bibliographies of recent Ph.D. projects, most refer to the framework of institutional initiatives intended to promote international awareness, where the language of the document is always a relevant condition.

The evolution of this literary production demonstrates a progressive systematisation based on work carried out in the area of material characterisation and associated with a pedagogical objective, among which the contributions of Craterre-ENSAG from the 1980s onwards stand out.

Although monographic work on geographical circumscription has always been present as an object of study, publications of research projects and scientific conferences have become the dominant format and have increased exponentially since the turn of the century.

In recent years, the conservation of earthen architecture heritage has benefited from structural behavioural studies in the more technical aspects and has experienced a wide spectrum of applications to the suitability of material intervention.

Accompanying this trend, the evidence of a conceptual approach with greater specificity is also confirmed, demonstrating convergence in the area of conservation theory with direct repercussions in heritage charts and other international reference documents.

Far from thematic exhaustion, the area has shown an openness to meet the most recent challenges, exploring delicate areas such as environmental and cultural sustainability and exposing strong concern for the importance of involving communities in such processes and the regeneration of the principles of the construction tradition.

Regarding the referential framework, this paper consolidates the perspective of general 5-point categorisations of the earthen vernacular heritage based on specific paradigmatic moments, which have been widely perceived as unrelated contributions. This nonlinear interpretation has been responsible for unbalanced literature production; more focus has been placed on the object of study documentation than on problematic evolution. This article claims the importance of consubstantiating a theoretical common ground beyond technical characterisation.

Abbreviations

ISCEAH	ICOMOS Scientific Committee on Earthen Architectural Heritage
CIAV	Vernacular Architecture International Committee
VERSUS	Vernacular Heritage for Sustainable Architecture
HBIM	Historic Building Information Modeling
WHEAP	World Heritage Earthen Architecture Programme

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References

Achenza, Maddalena, Marco Cadinu, Mariana Correia, and Amadeo Serra. 2006. *Houses and cities built with earth: Conservation, significance and urban quality*. Italia: Argumentum.

Achenza, Maddalena, and Chiara Cocco. 2015. Lectures A web map for Italian earthen architecture. In *Earthen architecture: Past, present and future*, edited by C. Mileto, F. Vegas, and V. Cristini. London: CRC Taylor and Francis.

Achenza, Maddalena, Mariana Correia, and Hubert Guillaud. 2009. *MEDITERRA 2009: 1st Mediterranean conference on earthen architecture*. Monfalcone: Edicom Edizioni.

Asprone, Domenico, Fulvio Parisi, Andrea Prota, Luigi Fenu, and Valeria Colasanti. 2016. Adobe in Sardinia. Static and dynamic behaviour of the earthen material and of adobe constructions. In *Brick and Block Masonry: Proceedings of the 16th International Brick and Block Masonry Conference, Padova, Italy, 26-30 June 2016*, edited by Claudio Modena, F. da Porto, and M.R. Valluzzi, 821–828. London: CRC Press. https://doi.org/10.1201/b21889-102.

Asquith, Lindsay, and Marcel Vellinga. 2006. *Vernacular architecture in the twenty-first century: Theory, education and practice*. London: Taylor & Francis.

Avrami, Erica, Hubert Guillaud, and Mary Hardy, eds. 2008. *Terra literature review: An overview of research in earthen architecture conservation*. Los Angeles: GCI.

Bendakir, Mahmoud. 2009. *Les Vestiges De Mari: La Préservation D'Une Architecture Millénaire en Terre*. Paris : Éditions de la Villette.

Bertagnin, Mauro, and Désirée De Antoni. 2012. Preventive Maintenance of an Himalayan Earthen Temple and Studies on Its Reduced Scale Model. In *Rammed Earth conservation - proceedings of the first international conference on rammed Earth conservation, RESTAPIA 2012*, edited by Camilla

Mileto, Fernando Vegas, and Valentina Cristini, 625–629. Valencia: CRC Press.
Bertagnin, Mauro, and Ali Ould Sidi. 2014. *Manuel Pour La Conservation de Tombouctou*. Paris: UNESCO.
Blondet, Marcel, and Rafael Aguillar. 2007. *Seismic protection of earthen buildings, international conference of seismic engineering*. Peru: Lima.
Brock-Nannestad, George. 2000. The Rationale behind Operational Conservation Theory. In *Conservation without Limits: IIC Nordic Group XV Congress*, edited by R. Koskivirta, 21–33. Helsinki: IIC Nordic Group.
Bui, Quoc-Bao, Jean-Claude Morel, Stéphane Hans, and Nicolas Meunier. 2008. Compression behaviour of non-industrial materials in civil engineering by three scale experiments: the case of rammed earth. *Materials and Structures* 42: 1101–1116. https://doi.org/10.1617/s11527-008-9446-y.
Campiani, Arianna, Ashley Morgan Lingle, and Nicola Lercari. 2019. Spatial Analysis and Heritage Conservation: Leveraging 3-D Data and GIS for Monitoring EarthenArchitecture. *Journal of Cultural Heritage* 39:166–176. https://doi.org/10.1016/j.culher.2019.02.011.
Canivell, Jacinto. 2012. Characterization methodology to efficiently manage the conservation of historical rammed-Earth buildings. In *Rammed Earth Conservation - proceedings of the first international conference on rammed Earth conservation, RESTAPIA 2012, Valencia, Spain 21–23 June 2012*, edited by Camilla Mileto, Fernando Vegas, and Valentina Cristini, 283–288. Valência: CRC Press.
Carlos, Gilberto Duarte, Mariana Rosado Correia, Sandra Rocha, and Pierre Frey. 2015. Vernacular architecture? In *Seismic retrofitting: Learning from vernacular architecture*, edited by M. Correia, P.B. Lourenço, and H. Varum, 11–16. London: CRC Press / Balkema / Taylor & Francis Group.
CERKAS and GCI. 2016. *Conservation and rehabilitation plan for Tighermt (Kasbah) Taourirt*. Los Angeles: GCI.
Checa, José Ramón Ruiz, and Valentina Cristini. 2012. Peruvian earthen architecture: Reflections on traditional constructive techniques. In *Rammed Earth conservation - proceedings of the first international conference on rammed Earth conservation, RESTAPIA 2012, Valencia, Spain 21–23 June 2012*, edited by Camilla Mileto, Fernando Vegas, and V. Cristini, 563–568. Valência: CRC Press.
Correia, Mariana. 2007a. *Taipa no Alentejo / rammed earth in Alentejo*. Lisbon: Argumentum.
Correia, Mariana. 2007b. Teoría de La Conservación y Su Aplicación Al Patrimonio En Tierra. *APUNTES - Journal of Cultural Heritage Studies* 20 (2): (Earthen Architecture) 202–19.
Correia, Mariana. 2016. *Conservation in earthen heritage - assessment and significance of failure, criteria, conservation theory, and strategies*. Newcastle upon Tyne: Cambridge Scholars Publishing.
Correia, Mariana, and Maria Fernandes. 2006. The conservation of Earth architecture: The contribution of Brandi's theory. In *International seminar on theory and practice in conservation, a Tribute to Cesare Brandi*, edited by J. Delgado Rodrigues and J. Manuel Mimoso, 233–241. Lisbon: Laboratório Nacional de Engenharia Civil.
Correia, Mariana, and Nicholas Walliman. 2014. Defining criteria for intervention in earthen-built heritage conservation. *International Journal of Architectural Heritage: Conservation, Analysis, and Restoration* 8 (4): 581–601. https://doi.org/10.1080/15583058.2012.704478.
Correia, Mariana, Letizia Dipasquale, and Saverio Mecca, eds. 2011. *TERRA EUROPAE: Earthen architecture in the European Union*. Pisa: Edizioni ETS.
Correia, Mariana, Pamela Jerome, Marcial Bondet, and Maddalena Achenza, eds. 2012. *Terra 2012 - XII SIACOT. XIth international conference on the study and conservation of earthen architectural heritage*. Lima: Argumentum.
Correia, Mariana, Gilberto Carlos, and Sandra Rocha, eds. 2014. *Vernacular heritage and earthen architecture. Contributions for sustainable development, proceedings of the international conference CIAV 2013 | 7°ATP | VerSus*. London: CRC Press Taylor and Francis Group.
Correia, Mariana, Letizia Dipasquale, and Saverio Mecca, eds. 2014. *Versus: Heritage for tomorrow. Vernacular knowledge for sustainable architecture*. Florence: Firenze University Press.
Correia, Mariana, Paulo Lourenço, and Humberto Varum. 2015. *Seismic retrofitting: Learning from vernacular architecture*. London: CRC Press Taylor and Francis Group.
Correia, Mariana, Marcial Blondet, Pamela Jerome, and Maddalena Achenza, eds. 2016b. *TERRA 2012 | SIACOT proceedings: 11th international conference on the study and conservation of earthen architectural heritage | 12th Iberian-American seminar on earthen architecture and construction*. Lisbon: Argumentum.
Correia, Mariana, Luis Fernando Guerrero, and Anthony Crosby. 2016. Technical strategies for conservation of earthen archaeological architecture. *Conservation and Management of Archaeological Sites* 17 (3): 224–256. https://doi.org/10.1080/13505033.2015.1129799.
Correia, Mariana, Célia Neves, Luis Fernando Guerrero, and Hugo Pereira Gigogne, eds. 2016a. *Arquitectura de tierra em América Latina*. Lisboa: ARGUMENTUM & PROTERRA.
Dachverband Lehm e.V. 2012. LEHM 2012 the 6th International Conference on Building with Earth, Weimar, Germany.
Dachverband Lehm e.V. n.d. Multilingual Terminology Glossary for Building with Earth. Accessed 15 Sept 2016. http://www.earthbuilding.info/glossary/.
Dethier, Jean. 2019. *Habiter la terre. L'art de bâtir en terre crue: traditions, modernité et avenir*. Paris: Flammarion.
Dipasquale, Letizia, Mariana Correia, and Saverio Mecca, eds. 2020. *From vernacular to world heritage*. Florence: Firenze University Press.
Dowling, Dominic, and Bijan Samali. 2009. Low-cost and low-tech reinforcement systems for improved earthquake resistance of mud brick buildings. In *Proceedings of Getty Seismic Adobe Project 2006 colloquium, The Getty Conservation Institute, Los Angeles, California*, edited by M. Hardy, C. Cancino, and G. Ostergren, 23–33.
Feilden, Bernard, and Jukka Jokilehto. 1998. *Management guidelines for world cultural heritage sites*. 2nd ed. Rome: International Centre for the Study of the Preservation and Restoration of Cultural Property, ICCROM.
Frey, Pierre. 2010. *Learning from the vernacular. Towards a new vernacular architecture*. Lausanne: Actes Sud.
Graciani, Amparo, Juan Martín, Gregorio Mora, Francisco Alejandre, and Jacinto Canivell. 2012. Preliminary studies for intervention, interpretation and value enhancement of tower of Don Fadrique (Albaida, Seville, Spain). In *Rammed Earth Conservation - proceedings of the first international conference on rammed Earth conservation, RESTAPIA 2012, Valencia, Spain 21–23 June 2012*, edited by Camilla Mileto, Fernando Vegas, and Valentina Cristini, 345–350. Valência: CRC Press.
Houben, Hugo, and Hubert Guillaud. 1989. *Traité de Construction en Terre*. Marseille: Editions Parenthéses.
Houben, Hugo, and Hubert Guillaud. 1995. *Earth construction: A comprehensive guide*. London: Intermediate Technology Publications.
Hwang, Heyzoo, Hubert Guillaud, and David Gandreau, eds. 2011. *TerrAsia 2011: International conference on earth architecture in Asia*. Grenoble: TerraKorea Craterre.
ICOMOS. 1999. Charter on the built vernacular heritage.
ISCEAH. 2021. *ICOMOS - ISCEAH glossary of earthen materials deterioration patterns*. Paris: ICOMOS.
Jaquin, Paul, Charles Augarde, and Christopher Gerrard. 2008. Chronological description of the spatial development of rammed Earth techniques. *International Journal of Architectural Heritage* 2 (4): 377–400. https://doi.org/10.1080/15583050801958826.
Joffroy, Thierry, ed. 2005. *Traditional conservation practices in Africa. ICCROM con*. Rome: ICCROM.
Joffroy, Thierry, ed. 2012. *Inventaire de l'architecture de Terre*. Grenoble: CRAterre.
Joffroy, Thierry, Hubert Guillaud, and Chamsia Sadozaï, eds. 2017. *Terra Lyon 2016 actes/proceedings/actos of the 12th world congress on earthen architecture*. Villefontaine: CRATerre.
Jokilehto, Jukka. 2003. Conservation vs. development in historic urban areas. In *ICHO, Post-Prints of the Terra 2003: 9th International Conference on the Study and Conservation of Earthen Architecture, Yazd, Iran*, 11–18. Iran: Deputy of Presentation, Iranian Cultural Heritage Organization.
LEHM. 2016. Conference proceedings of the 7th International Conference on Clay Construction, Dachverband Lehm e.V. (Ed.), Eigenverlag Dachverband Lehm e.V.: Weimar
Lercari, Nicola. 2019. Monitoring Earthen Archaeological Heritage using Multi-Temporal Terrestrial Laser Scanning and Surface Change Detection. *Journal of Cultural Heritage* 39:152–165. https://doi.org/10.1016/j.culher.2019.04.005.
Li, Zuixiong, Xudong Wang, Manli Sun, Wenwu Chen, Qinglin Guo, and Zhang Huyuan. 2011. Conservation of Jiaohe ancient earthen site in China. *Journal of Rock Mechanics and Geotechnical Engineering* 3 (3): 270–281. https://doi.org/10.3724/SP.J.1235.2011.00270.

López-Manzanares, Fernando Vegas, and Camilla Mileto, eds. 2001. *Revista Loggia: Arquitectura & Restauración, 12*. Valencia: Servicio de Publicaciones Universidad Politécnica de Valencia.
Miccoli, Lorenzo, Urs Mueller, and Patrick Fontana. 2014. Mechanical behaviour of earthen materials: A comparison between earth block masonry, rammed earth and cob. *Construction and Building Materials* 61: 327–339.
Miccoli, Lorenzo, Angelo Garofano, Patrick Fontana, and Urs Mueller. 2015. Experimental testing and finite element modelling of earth block masonry. *Engineering Structures* 104: 80–94. https://doi.org/10.1016/j.engstruct.2015.09.020.
Mileto, Camilla, and Fernando Vegas. 2017. *Proyecto Coremans, Criterios de intervención en la arquitectura de tierra. Catalogo de publicaciones del Ministerio de educación, cultura y deporte*.
Mileto, Camilla, Fernando Vegas, and Valentina Cristini, eds. 2012. *Rammed earth conservation, proceedings of the RESTAPIA first international conference on rammed earth conservation*. London: CRC Press Taylor and Francis Group.
Mileto, Camilla, Fernando Vegas, Lidia Garcia Soriano, and Valentina Cristini, eds. 2015. *Earthen architecture: Past, present and future, proceedings of the international conference on vernacular heritage, sustainability and earthen architecture*. London: CRC Press Taylor and Francis Group.
Mileto, Camilla, Fernando Vegas, Lidia Garcia Soriano, and Valentina Cristini, eds. 2018. *Vernacular and earthen architecture. Conservation and sustainability, proceedings of the international conference on vernacular earthen architecture, conservation and sustainability, SOS Tierra 2017 | RESTAPIA 2017 | VerSus 2017*. London: CRC Press Taylor and Francis Group.
Minke, Gernot. 2003. *Earth construction handbook*. Boston: WIT press.
Oliver, Paul. 2003. *Dwellings: The vernacular houses world wide*. London: Phaidon Press.
Oliveira, Cristina, Dora Silveira, Humberto Varum, Fulvio Parisi, Lorenzo Miccoli, Mario Solís, José D. Rodríguez-Mariscal, et al. 2021. Mechanical Characterization of Adobe Masonry. In *Structural Characterization and Seismic Retrofitting of Adobe Constructions: Experimental and Numerical Devolpments*, edited by Humberto Varum, Fulvio Parisi, Nicola Tarque, Dora Silveira, 55–93. Cham: Springer Nature. https://doi.org/10.1007/978-3-030-74737-4_4.
Orihuela, Antonio, and José Miguel Castillo-Martínez. 2012. Restoration of the Andalusí Wall of the Alcazaba Antigua (ancient citadel) of Granada (Spain). In *Rammed Earth Conservation - proceedings of the first international conference on rammed Earth conservation, RESTAPIA 2012, Valencia, Spain 21–23 June 2012*, edited by Camilla Mileto, Fernando Vegas, and Valentina Cristini, 401–406. Valência: CRC Press.
Parisi, Fulvio, Marcial Blondet, Andrew Charleson, and Humberto Varum. 2021. Seismic strengthening techniques for adobe construction. In *Structural Characterization and Seismic Retrofitting of Adobe Constructions: Experimental and Numerical Devolpments*, edited by Humberto Varum, Fulvio Parisi, Nicola Tarque, Dora Silveira, 183–209. Cham: Springer Nature. https://doi.org/10.1007/978-3-030-74737-4_8.
Pradines, Stéphane. 2018. *Earthen architecture in Muslim cultures*. Leiden: Brill NV.
Rainer, Leslie, and Angelyn Bass Rivera, eds. 2006. *The conservation of decorated surfaces on earthen architecture. In international colloquium*. Los Angeles: Getty Conservation Institute.
Rainer, Leslie, Angela Bass Rivera, and David Gandreau, eds. 2011. *Terra 2008: The 10th International Conference on the Study and Conservation of Earthen Architectural Heritage*. Los Angeles: The Getty Conservation Institute.
Rapoport, Amos. 1972. *Vivienda y Cultura*. Barcelona: Editorial Gustavo Gili.
Rauch, Martin. 2014. *New perspectives in building with earth. Archi'Terre 2014. École Polytechnique D'architecture & D'urbanisme D'alger. 19–24 April, Algeria*.
Ribeiro, Telma. 2021. Conservation of Earth Heritage: An Approach for a New Methodology. PhD diss., NOVA University of Lisbon. http://hdl.handle.net/10362/117649.
Rocha, Miguel. 2012. The citadel of Reina (Badajoz, Spain)—10 years of interventions on its walls. In *Rammed Earth Conservation - proceedings of the 1st International Conference on Rammed Earth Conservation, RESTAPIA 2012, Valencia, Spain 21–23 June 2012*, edited by Camilla Mileto, Fernando Vegas, and Valentina Cristini, 199–204. Valência: CRC Press.
Rudofsky, Bernard. 1990. *Architecture without architects: A short introduction to non-Pedrigreed architecture. Exhibition catalogue, Museum of Modern art (MoMA) New York, 9-11-1964 to 7-2-1965*. 3rd ed. Albuquerque: University of New Mexico Press.
Ruskin, John. (1851) 2003. *The stones of Venice*. Cambridge: Da Capo Press.
Scalesse, Tomasso. 1980. *Architecttura Povera*. Roma: Carucci.
Schädler-Saub, Ursula, and Boguslaw Szmygin, eds. 2019. *Conservation ethics today: Are our conservation-restoration theories and practice ready for the 21st century?* Florence: International Scientific Committee on Theory and Philosophy of Conservation and Restoration.
Shao, Yong, Gisle Jakhelln, and Mariana Correia, eds. 2019. *Vernacular and earthen architecture: Towards local development, proceedings of the 2019 ICOMOS CIAV and ISCEAH international conference*. Shanghai: Tongji University Press.
Silveira, Dora, Cristina Oliveira, Humberto Varum, Ioannis Ioannou, Lorenzo Miccoli, Nicola Tarque, Fulvio Parisi, et al. 2021. Mechanical Characterization of Adobe Bricks. In *Structural Characterization and Seismic Retrofitting of Adobe Constructions: Experimental and Numerical Devolpments*, edited by Humberto Varum, Fulvio Parisi, Nicola Tarque, Dora Silveira, 35–54. Cham: Springer Nature. https://doi.org/10.1007/978-3-030-74737-4_3.
Silveira, Dora, Humberto Varum, Anibal Costa, and José Carvalho. 2015. Mechanical properties and behavior of traditional adobe wall panels of the Aveiro district. *Journal of Materials in Civil Engineering* 27 (9). https://doi.org/10.1061/(ASCE)MT.1943-5533.0001194.
Tolles, Leroy. 2009. Getty seismic adobe project research and testing program. In *Proceedings of Getty seismic adobe project 2006 colloquium*, edited by M. Hardy, C. Cancino, and G. Ostergren, 34–41. Los Angeles, California: The Getty Conservation Institute.
UNESCO. 2020. New Inscribed Properties 2020. https://whc.unesco.org/en/newproperties/. Accessed 24 Jan 2020.
UNESCO. 2012. *The Kyoto vision*. Paris: UNESCO.
Vargas-Neumann, Julio. 1993. Earthquake resistant rammed earth (tapial) buildings. In *7a conferencia internacional sobre o estudo e conservação da arquitectura de terra*, 140–151. Lisboa: DGEMN.
Varum, Humberto, Fulvio Parisi, Nicola Tarque, and Dora Silveira. 2021. *Structural Characterization and Seismic Retrofitting of Adobe Constructions: Experimental and Numerical Devolpments*. Cham: Springer Nature. https://doi.org/10.1007/978-3-030-74737-4.
Vegas, Fernando, Camilla Mileto, and Valentina Cristini. 2014. Constructive features and preservation work of rammed Earth architecture: The Islamic tower of Bofilla (Valencia). *Journal of Architectural Conservation* 20 (1): 28–42. https://doi.org/10.1080/13556207.2014.886377.
Vissac, Aurélie, Ann Bourgès, David Gandreau, Romain Anger, and Laetitia Fontaine. 2017. *Argiles & Biopolymères*. Villefontaine Cedex: CRAterre.
Warren, John. 1993. *The conservation of brick and Earth structures: A handbook*. Sri Lanka: Sri Lanka National Committee of ICOMOS for the International Council of Monuments and Sites.
Warren, John. 1999. In *Conservation of Earth structures, series in conservation and museology*. Oxford: Taylor & Francis Ltd.

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