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Vernacular earthen architecture. Construction techniques and restoration. From the international setting to some specific Italian regional cases

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Abstract
The research focuses on vernacular architecture, in particular earth buildings, highlighting the different geographic areas involved, building types and construction techniques. In Italy, despite theoretical progress, some cultural and technical problems are still evident in earth architecture conservation. This is also due to the prevalence, among earth buildings, of vernacular architecture, that, in general, has no artistic value and with historical value yet to be fully appreciated. The characteristics of some regional areas are also considered, with particular attention to the Marche and Sardinia Regions, where earthen constructions have existed since ancient times. Knowledge of construction techniques that are the result of age-old experience is the basis for a good conservation and for the design of new ones. Today, some public administrations, on the regional and local levels, have developed operating manuals for the conservation of earth constructions, but there is still no real legislative protection for earth buildings and their material authenticity.

Keywords: *vernacular architecture; earth building; conservation; sustainability.*

1. Introduction

The issue of earth building is becoming increasingly urgent within the discipline of architectural restoration, both due to the perishability of the material when it is not properly maintained, and because conservation efforts either result in the simple reconstruction of entire portions of buildings or are transformed into operations that completely alter their structure. Within an international framework of reference, the intention is to update the state of Italian reflection on the subject through the review of the existing literature, with reference to Sardinia and Marche Region.

2. The international landscape

For several years, scant durability in the absence of maintenance has brought earthen constructions to the centre of reflections, in an international setting, within the discipline of restoration. The specialist literature on the subject has consisted mainly of frequent international conferences, which have the merit of regularly assessing the current state of thought. ICOMOS spearheaded these meetings, organizing two important international conferences in Yazd, Iran, in 1972 and 1976, aimed at defining and sharing the value of earth architectures. These were followed by a host of

others: in Turkey (1980), Perù (1983), Italy (1987), the United States (1990), Portugal (1993), the United Kingdom (2000), Iran (2003), Mali (2008), Peru (2012), and in France (2016). TERRA 2022, to be held in the United States (Santa Fe) is already being planned, to be followed by TERRA 2024 in Ecuador (Cuenca). In 2021, a collaboration between the National Research Council of Italy (CNR) and the Chinese Academy of Cultural Heritage (CACH) saw the publication of the results of certain studies carried out on earthen constructions and on the different possibilities for conserving them, in various parts of the world[1]. In general, reflections on the conservation of buildings of this kind vary according to the geographic location where they are made. While there is great interest in the decay owing to weathering, in the more seismically active areas attention focuses mainly on low resistance to earthquakes and on experimenting with possible interventions to improve their structural response[2]. Recently, interest in these constructions has also related to their eco-sustainability.

2.1 Earthquake resistance

The 1998 European Macroseismic Scale lists adobe structures among those most vulnerable to earthquakes. Walls made in *pisé* are generally more resistant than those in *adobe* (by up to 40%). The parameters that influence the seismic vulnerability of *adobe* are the granulometry of the earth used, the moisture content, the level of compaction, the use of natural additives, and the treatment of the joints (which is to say the introduction of materials other than earth between the layers)[3]. On the seismic vulnerability of *adobe* structures, the studies begun in California in 1990 by the Getty Foundation with the *Getty Seismic Adobe Project* (GSAP) remain fundamental[4]. The GSAP's final report noted the inadequacy of the consolidation techniques used to that time, since they were the cause of irreparable damage unacceptable in buildings of historic and artistic value. In some of the interventions studied by the GSAP, the central part of earthen walls had been replaced with elements in reinforced concrete[5], or cages of beams and pillars in reinforced concrete had been employed[6]. The objective of the research was to find reinforcement techniques to keep the walls from toppling during a quake. The indicated solution was the use of slabs, whose beams function as chains if appropriately connected to the exterior walls as in common masonry buildings. Researchers also verified the effects of introducing vertical steel bars in the walls, steel tie rods in the masonry units, and nylon straps applied horizontally and vertically to increase the connection between the partitions, thereby improving the structures' monolithic behaviour. The various systems have yielded good results and can be employed on a "case-by-case" basis depending on whether the intention is to preserve the integrity of the surfaces and of the exterior decorations (internal bars) or to facilitate the reversibility of the intervention (straps)[7]. Reinforcement techniques using natural,

Rossana Mancini wrote paragraph 2, Maria Giovanna Putzu paragraphs 3 and 5, and Enrica Petrucci paragraph 4.

[1] The project was financed by the National Research Council of Italy (CNR) and the Chinese Academy of Cultural Heritage (CACH); Luvidi, Fratini, Rescic, Zhang 2021.

[2] Meli, Hernandez, Padilla 1980.

[3] The available literature on the seismic resistance of cob (rammed earth) constructions is quite limited. Interesting results are in Bu, Wang, Han, Li 2011.

[4] The *Getty Seismic Adobe Project* was discussed for the first time at the Sixth International Conference on Earthen Architecture, *Adobe 90* (Oct. 1990 a Las Cruces - New Mexico), after the Loma Prieta earthquake (1989) in California, which destroyed many historic buildings in *adobe* (Tolles, Kimbro, Webster, Ginell 2000).

[5] An example of this kind of intervention are the Sonoma Barracks in Sonoma State Historic Park, California.

[6] The Plaza Hotel in San Juan Bautista State Historic Park, and the Cooper-Molera Adobe in Monterey, both in California.

[7] This kind of reinforcement is appreciated for its ability to go into action only if necessary, to avoid stiffening the structure, and to guarantee structural continuity between the walls and the partitions and the bearing walls' containment. Interest in these studies is still lively and references to the obtained results are found even in the most recent international meetings (Webster 2016). A system of traditional consolidation, carried out during the building's construction phase, was discovered in Bam, in southeast Iran, after the 2003 earthquake. This involved supporting the roofs, to keep them from collapsing, not only with exterior walls, but also with wooden columns placed in the thickness of the wall sections.

environmentally friendly materials have been tested in Peru since 1972, after the long series of earthquakes coming in succession since 1940[8]. It has been shown, for example, that the insertion of bamboo canes into the adobe wall sections was able to increase their deformation capacity. Between 1990 and 2000, the Regional Centre of Seismology for South America (CERESIS), the German Agency for International Development (GTZ) and the Pontifical Catholic University of Lima (PUCP) tested the use of natural fibre ropes, wood, and steel mesh in the critical points of the constructions. In 2004, a joint project between the Pontifical Catholic University of Lima and the Getty Conservation Institute assessed the effects of external reinforcements made using natural and industrial mesh on both sides of the adobe walls, demonstrating that, in the event of severe earthquakes, flexible materials offer better performance than stiff ones.

2.2 Resistance to weathering

Earth architecture requires regular maintenance in order to keep the external protection systems (plaster and roofs) efficient. Therefore, preventive conservation is highly important in order to avoid the continuous renewal of these external elements, and the consequent loss of the building's authenticity. The constant reconstruction activity has shifted attention from conserving the work to safeguarding traditional techniques, so as to restore "in keeping with tradition"[9]. This is theorized, for example, in Central America, by the *Chilean LSC Atlas project*, which offers a critical vision of the use of non-local techniques and of industrial materials in "vernacular" architecture, for the purpose of conserving the original construction logic more than the authenticity of the material[10]. Meanwhile, a positive evolution from reconstruction/recovery to conservation and protection is found in the Chan Chan site on the northern coast of Peru. Between 1964 and 1969, major reconstructions were done, largely oriented towards formal recovery; however, at a second moment, work began to stabilize the existing structures by creating large wear surfaces. Some wall tops were covered by capping made using a clay mortar with the addition of an acrylic emulsion and other substances like wood glue, but the results were poor, due likely to the high rate of humidity at the site. Better results were attained using ethyl silicate[11]. A new phase of interventions was embarked on after 1998, following the atmospheric phenomenon known as *El Niño*, when prevention efforts were carried out by screening the ancient walls with bamboo and thatch barriers to protect them from the weather. Plant fencing has also been proposed in some sites in Saudi Arabia to defend the remains from sandstorms[12]. Only in some rare cases have restoration materials been made distinguishable from the pre-existing elements. The cases that have been tried out include the insertion, between the surface wear layers and the original wall, of layers of geotextile material, or of earth and small coloured beads.

3. The national situation

In Italy, earth construction tradition is very ancient, as witnessed by numerous archaeological finds and by classical sources that describe the employed techniques with an abundance of detail. The use of earth has thus gone on since antiquity, with variations and alternations, but always with continuity over the course of the centuries, until the early 1950s. In Italy, like other European countries, earthen buildings are present, with different intended uses and different typological characteristics (house, small building, villa, school, church, etc.), in both rural and urban settings. An examination of the data provided by earlier

[8] Vargas-Neumann, Otazzi 1986.
[9] Bartolomucci 2013.
[10] Suilan Hau Espinosa, Jarpa 2016.
[11] On the use of ethyl silicates to consolidate *adobe* structures in the late 1980s, see Chiari 1988. On the Chan Chan site, see Morales Gamarra 1983.
[12] Mancini, Putzu 2019, p. 735.

studies[13] shows that all Italian regions, with the exception (based on the knowledge acquired to date) of Valle d'Aosta, traditionally saw the use of earth construction techniques, with technical and formal solutions often differing from one another[14]. Moreover, as in the other non-Italian settings affected by the phenomenon, there is a strong link between the presence of large river or lake areas, which promote the deposit of clays, and the consolidation of an earth construction tradition (Po plain; subcoastal zones of Marche and Abruzzo; area of the Agri and Sinni River basin in Basilicata; Tirso valley in Sardinia)[15]. It is also noted that beyond the presence of clay in the subsoil, a fundamental role in spreading earth constructions is also played by climate conditions (temperature, rainfall, latitude and elevation) that condition appearance and persistence. Although Italy is home to all the construction techniques typical of the vernacular tradition of other European countries, particularly widespread among those involving the use of earth are *adobe*, *pisé*, and, to a lesser degree, *torchis*. In spite of the process of neglect that began in the second post-War period, and although, until the second half of the twentieth century, quite little was known about earth construction techniques and there was a widely-held conviction that they had fallen entirely into disuse, some studies have actually demonstrated that in the 1960s, in certain regions of Italy, earth was still used following traditional procedures[16]. Starting from the 1980s, the new approach towards a way of building that presented features of sustainability and respect for the environment saw in earth construction all the technical characteristics that suit it for the building of healthy, pollution-free environments[17]. Although the earth sector now has numerous results of international research and studies at its disposal, there is still no national-level legislation that recognizes earth as a construction material and that provides technical rules of reference to regulate and define the types of intervention suitable both for historic construction and for constructing parts or entire buildings *ex novo*[18].

4. Earthen houses in the Marche

In the Marche region, the earth construction technique was used until the nineteenth century. As late as 1934, *Indagine sulle case rurali in Italia* found about 1,401 dwellings in the Marche built in earth and thatch using the technique called *a massone* or *maltone*. In Pesaro, 14 houses were censused, 95 houses in Ancona, 931 in Macerata, and 361 in Ascoli Piceno[19]. The first to raise doubts as to the truthfulness of these data was Clarice Santoponte Emiliani, who several years later was to perform her own fact-finding survey aimed exclusively at earth constructions, discovering a reality that was quite different[20]. According to Santoponte, the number reported in the 1934 was to be considered erroneously low due to significant errors made in gathering information and due to the desire to conceal or at least to reduce the presence of these buildings.

Fig. 1. House in the Macerata area, in accordance with the typical construction technology, 2020.

[13] Bertagnin 1999; Baldacci 1958; Lasalandra 2008; Manca, Cossu, Loche 2005; Mancini, Putzu 2019.

[14] In particular, according to the data provided by CeDTerra (documentation centre on earthen houses; see also the rich bibliography provided there), on national territory, earthen houses, widespread above all in Sardinia and Abruzzo, are also present in Emilia Romagna, part of Veneto, Lombardy, Piedmont, Tuscany, Marche, Molise, Basilicata, and Calabria. Other construction types were noted for example in the Marengo plain (Alessandria), where we find buildings like the Pasturana church and the Spinetta Marengo school, and in Quartu Sant'Elena (Cagliari), where there are numerous small urban buildings (Bertagnin 1999, pp. 24, 25).

[15] Lasalandra 2008, p. 256; Galdieri 1987.

[16] Lasalandra 2008, p. 258.

[17] Bertagnin 1999, p. 285.

[18] Currently, Law no. 378 of 24 December 2003, *Provisions for the protection and valorization of rural architecture*, is the only regulation that also relates, albeit marginally, to earth constructions, for which, for now, only proposed and draft laws have been developed.

[19] Istituto centrale di statistica del Regno d'Italia 1934.

[20] Santoponte Emiliani 1941, pp. 245-258.

Santoponte's research shows that most of the earth constructions were distributed in hilly areas with concentrations exceeding 20% in the Macerata area. These were the houses of day labourers, poor people, those who made do to eke out a living in the peasant economy; during the post-War period, with the exodus from the countryside, these houses underwent dramatic phenomena of abandonment. In those that survived, their earthen nature was concealed as much as possible, almost as if it were a mark of poverty and infamy for those who continued living in them. The construction technique consisted of mashing a mixture of clay and straw to obtain a dense, plastic compound, which was then divided into clumps weighing 5-10 kilogrammes each, coarsely shaped into cylinders tapered at the ends, averaging 15 cm wide and 20-30 cm long. To make the construction, these *massoni* were laid in layers from 50 to 70 high and 40 to 80 cm wide, to form a monolithic wall structure. Each layer was allowed to dry for several days, during which the wall was trimmed and squared.

Fig. 2. The construction process involves the entire family, photograph of 1919 from a private archive

Particular attention was devoted to site selection, both to avoid the problem of humidity, and because suitable earth had to be available in the vicinity, since transporting the raw material from a distance was not cost-effective. Foundations were shallow if not absent altogether. Once the building's perimeter was established, the area was dug out to a depth of between 50 and 100 centimetres; the earth was then placed back in the hole in 30/40-centimetre layers, adding water and straw and mashing it to blend together, and then allowed to dry. Once ground level was reached, the bearing walls began to be raised. The craftsman laid *massone* along the house's perimeter in one layer after the other, in alternating courses, or more rarely in herringbone courses inclined at 45°. Once a layer was completed, the craftsman crushed it down with his feet to fill in the cracks; he then smoothed it inside and out with his spade, sometimes working the earth with water again. As the layers progressed, the *massone* grew smaller, to allow them to be put them in place more easily; the walls thus tapered in, measuring about 80 cm at the base and 50 cm at the top. Given the nature of the material, the intersections of the walls represented the most delicate points in the construction; to solve the problem, the junctions between walls were often reinforced with horizontal connections of olive branches sunken into the structure. For two-storey houses, the floor slab was made at a height of about 220 centimetres, by anchoring poplar, elm, or oak beams to the wall, placed in parallel one metre apart, and topped by a second, denser, orthogonal frame of slats, upon which was placed a layer of mud-daubed reeds woven or twined together, which served as the base supporting the burnt brick floor. The same technique was used to build the roof, whose covering was made with bricks (*penci*) resting upon a mixture of soft earth atop a layer of woven reeds. The roof was rather overhanging – usually by more than 50 centimetres – to protect the walls near the ground. In general, only the north-exposed exterior wall was plastered; far more frequently, the use of plaster was limited to the outlines of doors and windows. For the base, the protection was made using burnt brick or stone, up to the height of about one metre. The analysis shows the great historic and cultural value of these constructions, as productive and life forms, that express the region's identity. Over the past decades, great interest in architectures of this kind has developed, thanks also to the numerous research efforts carried out by universities, the Region, and local institutions that have devoted themselves to studying the most significant

examples present in the Marche[21]. The analyses were brought together in a cataloguing data sheet, grouped into provincial settings in accordance with the density of earth construction.

4.1. A virtuous example. Recovery of the Village of Villa Ficana in Macerata

The heightened sensitivity to safeguarding this "minor" building heritage led, as in the case of the Ficana quarter in Macerata[22], to identifying multidisciplinary procedures aimed at recovering earth construction.

Fig. 3. The village of Villa Finacana in Macerata, after the restoration interventions, 2022.

To prevent the abandonment of this construction technique, an articulated programme was initiated in 2000. In 2014, the Municipality of Macerata held a competition for submissions of design proposals for museum interventions and the recovery of the buildings. The *Recovery Guidelines* defined the field of possible interventions, in such a way as to represent a binding basis for future recovery work, and to harmoniously and sustainably reconcile possible changes with the conservation of all the historical and cultural values that the village possesses. The *Guidelines* provide a working tool able to guarantee a high qualitative standard for future designs; at the same time, intended uses deemed compatible with the typological and size characteristics of earthen houses were identified. In recent years, this allowed the village to be restored to its original configuration, while also fostering the creation of a "museum of the earthen houses of the Marche."

5. In depth: Sardinia

In Sardinia, this technique has been attested since antiquity. Clayey earth, in fact, has been found in some early Iron Age nuragic sites, in private buildings from the Phoenician/Punic Age, and in Roman and Medieval sites[23]. The technique in mudbricks (*ladiri*), now more well-known, saw additional impetus during Spanish domination and was employed in subsequent centuries along with other materials (iron, brick, and reinforced concrete). Until the 1950s, *ladiri*, along with stone, was the building material most used in private construction (fig. 4).

Fig. 4. Earthen wall of a house in the town of Donigala Fenughedu (Oristano) (Source: Putzu, 2015).

The 1980s saw a revival of the technique, which appears widespread with certain variants in much of the regional territory; however, the historic and geographical regions where it is most prevalent are the areas of Campidano Maggiore and Campidano Meridionale, the Trexenta area, and the area of the Ogliastra plain. It is used mainly for residential construction: the courtyard house, the residential building, and the villa, but also for some industrial buildings. Absent an appropriate protocol, univocal and shared by the entire scientific world, a useful tool for

[21] Architetture di terra nelle Marche 2005. The volume collects the results of a research work on the building techniques and conservation methods of earth architecture constructions.

[22] The Village is in the northern zone of Macerata. Its origins date to about the nineteenth century, as witnessed by contemporary cadastres, and it covers an area of about 7,000 m^2. The demographic increase recorded in the nineteenth century saw houses proliferate exponentially in response to housing needs rising during those years within the poor class of farmers.

[23] Sanna, Atzeni 2009, p. 3; Putzu 2015, pp. 131-135.

construction practice may be seen in the manuals for the recovery of the historic centres of Sardinia, done at the initiative of the Region and the Urban Planning Councillorship[24]. Among the "good practices," useful reference data are provided both for structural interventions and for the technological characteristics of the individual component materials. In particular, in the case of possible reconstructions following collapse of entire walls, the use of similar and compatible materials and technologies is recommended; however, especially in buildings of particular testimonial significance, a distinction between the original and the reconstructed part (e.g: interposition of a shutter, working with undercut) ought to be made. The reconstruction of partition walls using "non-traditional" materials and techniques is not ruled out a priori, but "is deemed at any rate inadmissible, due to the incompatibility in thermohygrometric mechanical behaviour, and the use of concrete, whether or not reinforced"[25]. As concerns the interventions on the floor slabs, which in historic Campidano-area earthen construction always have a wooden structure, the support junction to the wall should advisably be well aerated, to guarantee good transpiration for the wood. In addition to the use of metal straps bound to the ends of the beams and anchored to key beams on the wall, an additional structure stiffening the masonry structure, which supplements the installation of chains and tie rods, may be made by introducing ring beams or hoops. Considering that the existing ring beams are usually made with rubble-core filling material, contained where needed by brick or stone cornices, these elements should advisably be "emptied, while still maintaining on the outer edge of the masonry a containment, to prepare the housing of the ring beam"[26]. Upon careful evaluation, it is considered admissible to use ring beams in appropriately reinforced concrete, while it is held that ring beams in cement must be excluded. Lastly, an essential component for conserving earth architectures is the plaster, based on common lime, better if in the form of slaked lime (grassello), or earth based. An excellent compromise may be found by making an earth-based mortar, adding lime in small amounts[27].

6. Conclusions

To date, the studies on earth structures, however abundant, are based on extremely heterogeneous survey material relating to existing structures, using no "univocal" criteria for interpretation. Moreover, there is still no thorough survey of existing structures that would be such as to provide a comprehensive picture of the current situation. Although some sensitive public administrations have developed targeted operating manuals and specific guidelines for restoration, there is still no legislative recognition protecting earth construction in its material authenticity and as a constituent element of historic fabrics.

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