Correia, M., & Guerrero, L. (2018). Conservation of Earthen Building Materials. The Encyclopedia of Archaeological Sciences, 1-6. https://doi.org/10.1002/9781119188230.saseas0117

Conservation of Earthen Building Materials

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Introduction

Earth (clay-rich soil) has been used as a building material since antiquity and throughout the history of humankind, though only recently has earthen architecture become scientifically accepted as a discipline of its own. Earthen architecture has been present in the five continents and reveals a wide range of cultural diversity of expressions, forms, techniques, and building styles through its historical heritage. Currently, there are still 15–17 percent of people living in earthen settlements (Correia 2016).

In recent decades, more interest, focus, and research have been given to the conservation of earthen heritage. World Heritage plays an important role in increasing worldwide interest, especially considering the outstanding value of some of the earthen sites that are at great risk. Creation of the *UNESCO World Heritage Earthen Architecture Program (WHEAP)* was meant to disseminate the international significance of this exceptional and fragile heritage. The survival of this heritage is a challenge that needs to be addressed with thoughtfulness, knowledge, and humbleness.

There are several publications on earthen architecture conservation. Most address the conservation of individual sites, and very few publications compare the different intervention approaches (Warren 1999; Matero and Cancino 2000; Mileto and Vegas 2014; Gandreau and Sadozai 2014; Correia, Guerrero, and Crosby 2015; Correia 2016). Consequently, this fact limits, in a way, the opportunity to establish critical reflections on the level of success and to apply the obtained results in present and future actions (Guerrero, Correia, and Guillaud 2012).

Unfortunately, there are great difficulties conserving earthen structures and preventing their decay. Several reasons for this can be identified: inadequate and inefficient intervention, lack of follow-up and maintenance, lack of preparation of the team members, incorrect intervention interpretation, and lack of material knowledge.

Failure of the physical condition of the structures may result from lack of action or discontinuation of conservation measures and conservation practice. However, as earth is such a fragile material, inaction to protect and conserve, in some instances, can endanger the timely preservation of the last remains. As defended by Cesar Brandi, sometimes the site can be beyond recovery, if the unity principle addressing the archaeological remains as a whole is not present anymore (Correia and Fernandes 2006).

Recurrent failure can also occur due to the use of incompatible materials and methods applied by professionals without enough specific knowledge or experience in earthen heritage conservation. More accurate testing and assessment is required before the use of new treatments and stabilization materials.

Universal solutions are also sometimes employed, using only one intervention approach. The problem might lie in the lack of research and knowledge of the material compatibility, its reversibility, and long-term impact. A clear understanding of earthen architecture, different earthen building styles, integration of local knowledge and skill, identification of seismic performance, differences of behavior regarding new intervention, a critical view of different intervention approaches, and their impact on the earthen fabric are required to encourage a change towards the conservation of this fragile heritage (Correia 2016).

The Encyclopedia of Archaeological Sciences. Edited by Sandra L. López Varela.

DOI: 10.1002/9781119188230.saseas0117

This is why a comprehensive knowledge of the different technical strategies of conservation should be documented and further critically assessed, before an informed decision can to be made, as each case is unique. Different technical strategies can be considered, such as preventive measures, modification of the earth mixture, use of consolidants, and structural reinforcement.

Preventive measures

One measure that in general guarantees safe conservation of earthen heritage is *reburial of the excavated structures*. Although this is an extremely drastic strategy with strong implications for the site value and accessibility, it provides priority to its comprehensive preservation in the long term. However, the procedures to rebury remains that have already been excavated, exposed, and documented should be extremely cautious, as once the site is reburied, it would be difficult to monitor the original remains. That is why, for the protection of very damaged earthen archaeological structures, the use of membranes such as geotextiles is recommended, which have the quality of physical barriers that allow the natural flow of water through the soil and the archaeological remains.

A less radical measure is the designing and placement of *protective shelters*. This measure has been proven effective for several decades in some cases, and ineffective in others due to wind dynamics. It has the advantage of favoring public visit to the sites, while protecting the site from possible damage caused by rain, wind, snow, or hail. However, any change in the temperature and humidity of the earthen structures sets their material integrity at risk, as much of their stability is derived from the equilibrium they possess with the amount of water they contain. An excessively humid earthen structure can disintegrate, but the same happens if the earthen structure is too dry, as it loses cohesion. As a result, when choosing shelters to cover earthen sites, the main aim should be the hygrothermal balance of the interior spaces. Shelters can also dramatically alter the visual relation of the archaeological sites. Therefore, their form, height, and materials must be carefully and sensibly designed (Figure 1).

Figure 1 Chan Chan is an earthen endangered archaeological site classified as World Heritage, in Trujillo, Peru.
Source: Photo by Mariana Correia, January 2017.

Figure 2 Arg-e Bam is an earthen citadel classified as World Heritage, in Bam, Iran.
Source: Photo by Mariana Correia, October 2011.

The structures exposed to the elements, and those protected by shelters, will require a preventive conservation intervention, involving a direct physical intervention, as, for example, the application of a *surface coating*. For a more balanced approach, it is indispensable to consider the hygrothermal requirements needed for earthen structures. This will protect the earthen structures from possible surface damage, without impeaching the natural permeability of the building components. Among the most frequently used technical strategies is the use of capping on the top of the walls (e.g., thatch), especially on walls that have lost their integrity. Also common is the use of sacrificial coatings on the top of the walls, and earthen renders on the vertical exposed surfaces.

For an adequate wall adhesion, these coatings are often made with an earth mixture like the original fabric, with the possibility of subsequent removal, as the reversibility principle should be considered. Sacrificial coatings generally have a higher amount of gravel or other aggregates, which improves erosion control and site stabilization. The surface coating should not be more rigid and impermeable than the original earthen fabric that needs to be protected, and it should receive regular maintenance. In earthen heritage, conservation should be part of a continuous preventive activity.

The use of geotextile membranes to protect the earthen structure before applying the surface coating can also be considered. These are often used on the reburial of excavated structures, as previously mentioned. They are useful because once covered with sacrificial coatings, they allow the natural flow of water vapor in the structures, generate a surface protection barrier, and can be removed when required. However, the membrane selection and application and its earthen coating should be addressed carefully. It often happens that, upon application, the elements and components of the site that were covered are no longer recognized, and the architectural value of the component is lost (Figure 2).

Modification of the earth material

Modified earthen materials usually create a more durable fabric. This can be achieved through stabilizers, additives, and adhesives that can turn the natural soil into a more effective earth mixture. These materials can be organic or inorganic, of natural or synthetic origin. *Stabilizers* are materials that modify the physical and chemical characteristics of natural earth, increasing its resistance to mechanical stress, as well as to the effects of moisture (Correia et al. 2015). The most common stabilizer is lime, but fired gypsum has also been used for a long time to improve the earth mixture. The earthen material that forms the sacrificial coatings, as well as some components designed to fill gaps in the original building systems, are often stabilized. This process consists of the modification of the natural qualities of the earth to allow it to acquire a greater mechanical resistance, adhesion, water resistance, and porosity.

For decades, cement was used as a soil stabilizer, or as a surface coating when addressing earthen heritage intervention. It was believed that its use could avoid periodic maintenance and could provide a more effective response to harmful weathering agents. However, as it has been widely documented, cement is incompatible with earth, due to its relative difference in permeability, mechanical strength, and contraction–dilation coefficient. This difference generates dynamisms within the earthen structures that progressively degrade it. The impermeability of cement traps water vapor inside the earthen material, which ultimately leads to the destruction of the structure. Therefore, its use is not recommended, and extensive interventions have been planned to carefully remove the cement capping.

Additive is a general term for substances that do not interfere with the chemical reactions of clay, but which provide a physical activity that improves its properties. Sand is one of the additives most frequently applied to balance the expansive and detractive activity of argillaceous soils (Correia et al. 2015). Different additives can be used, such as pulverized fly ash (PFA) and natural additives such as egg white, cactus juice, straw, chaff, wood chippings, and animal hair.

Several different additives have survived as part of the intangible vernacular knowledge. This is the case, for instance, with mucilage, juices, and gums of vegetable origin, as well as some animal proteins, which offer greater consistency to the earth mixture and improve its adhesion. This also improves the water resistance of the material, while maintaining the permeability of water vapor through the material. This is important because the earthen wall constantly balances air and humidity between the interior and exterior. A similar effect is achieved by adding small proportions of lime or gypsum to the earth mixture. These agents produce chemical reactions that with time provide a greater mechanical and water resistance to the earth mixture.

Adhesives are emulsions that bond soil particles together and are primarily valuable in attaching plasters to their substrates. The most common emulsions are acrylic emulsions, such as "copolymers of ethyl acrylate, methyl methacrylate, and/or ethyl methacrylate" (Oliver 2008). Some authors do not recommend the use of emulsions, due to their difficult penetration when there is an absorbent material, but also because they have no reliable additives in terms of material aging.

Use of consolidants

A consolidant is a material that is applied on surfaces to establish cohesion of the particles, thus providing greater protection against surface weathering. On earthen walls, *inorganic consolidants*—aqueous solutions and/or dispersions of different salts—are commonly employed. Once applied on surfaces, through the soil capillaries, they stabilize the clays and agglutinate them to smaller-size particles. This group includes substances used in traditional maintenance, such as limewater, potassium aluminum sulfate (alum), and alkaline silicates (sodium or potassium) (Correia 2016). They can be applied through spray or by paper and brush absorption.

There are also traditional materials, such as *natural organic consolidants*. This is the case with animal glue, gum, beeswax, egg white, casein, natural cactus juice, and so on. Each one has a different impact on the earthen surface. Some have a lower penetration than others, or can react with sensitivity to humidity. Others are more prone to biological attacks and can change color with time. Natural cactus juice is commonly used in Latin America, as it has a good balance between availability, price, and short-term impact, despite some experts arguing that for medium- and long-term impact it does not present enough positive outcomes.

Concerning the *synthetic organic consolidants*, several products have presented good results, as is the case with silica ester, ethyl silicate, polyvinyl alcohol (PVA), and polyvinyl acetate. One of the most popular products is ethyl silicate, due to its good penetration and longer lasting results maintaining the color and the wall's earthen fabric in good state. In Huaca de la Luca, Trujillo, Peru, it has been successfully used for over 20 years. However, its high cost restricts its use and sustainable application.

Silicone and synthetic resins are also frequently applied for surface protection. However, authors restrain their use for surface exterior treatment, as they tend to form a film on the surface and "with the exfoliation of this film and the detachment of the treated part, more damage is done to the surface to be protected than if it had not been treated at all" (Alva and Chiari 1995, 105).

Structural reinforcement

For the repair of damaged structures, *nonintrusive structural reinforcements* provide an option. When the damage to archaeological remains is so severe that their unity, load-bearing capacity, or survival are at risk, it becomes necessary to integrate systems of structural support. These systems must be carefully designed, so as not to alter the natural performance of earthen structures. Physical and chemical compatibility is essential in this case to achieve continuity in the transfer of mechanical stresses by filling-in missing parts. This is possible by applying mud grouts to fill-in cracks, or using bonding mortars to replace disintegrated earthen material. In the case of lacunas, the size of the gap should be considered to balance the structural filling. This does not mean that the original material must be replicated, as this could lead to the ethical dilemma of reconstruction and historical falsification. Unfortunately, this is a frequent choice in the case of earthen heritage, which is incorrectly chosen, as it is often considered by professionals that earthen reconstruction is acceptable in archaeological heritage, when it is not in other materials.

There are conditions in which the severity of the earthen archaeological remains guides the intervention design for radical adjustment regarding its transfer of loads, which only becomes possible through *intrusive structural reinforcement*. Because of earthquakes, differential sinks, flooding, or similar agents, the relation between the structural components can be interrupted, so that it becomes necessary to incorporate components that bind them together again. The introduction of supports allows the components to separately acquire a new condition of structural stability as isolated units. In both cases, it is necessary to consider that the difference between the strength of the remains and the reinforcements must be the smallest possible to avoid these measures being more harmful than beneficial.

Structural reinforcements made of wood, bamboo, or vegetable fibers have been found to be compatible with earthen structures, since they have similar coefficients of strength and dilatation. However, it is important to take care of the transition points between these reinforcements and the remains, so that balanced stress distributions are developed, instead of load concentrations.

In case there is a need to use materials with greater resistance than wooden structures, stone, brick, and even steel components have been used. However, it is necessary to generate a gradual unloading process in transition areas, allowing a gradual passage from a highly resistant material to the earthen built material. Intrusive structural reinforcement should be the last option for intervention and not the first choice to consider, as the principle of minimum intervention is essential when addressing earthen heritage intervention.

Conclusions

The development of intervention procedures for the conservation of earthen built heritage should be flexible, enabling suitable solutions for each case. It is necessary to consider the individuality of each site and that the conditions of the different sites need to lead to specific solutions. This is why documentation and registration of the different results obtained during conservation actions are required, in order to have a critical assessment of their level of success or failure, according to the specific conditions in which they were developed.

When addressing the conservation of earthen structures, one of the most serious errors is the search for a "permanent" solution. The development of expensive works addressing incompatible materials, cement-based mortars, or structures of reinforced concrete has led to irreparable damage to earthen heritage.

History of earthen architecture reveals that its structures are closely related to the societies that have inhabited them and have continuously maintained them. Thus, the solution for the preservation of this heritage should be based on a proper design of management processes from different time frames, based on consistent procedures. These actions necessitate the participation of communities to which the heritage belongs; thus, within planning for the management of the sites, actions to recover traditional knowledge and the practical transfer of earthen technology are of great importance (Guerrero 2015). The integration of local intangible heritage is part of a site's living traditions and preservation.

Lack of planning and strategies definition can involve reactive, instead of proactive, actions, which in the case of earthen architecture could have irreparable loss. A greater number of experts and conservation professionals with certified education on earthen heritage conservation would increase the quality standards and the expertise in the field.

For a balanced conservation approach addressing earthen archaeology, a comprehensive course of intervention needs to be established for each site, involving different stakeholders, an interdisciplinary expert team, and consideration of the different indicators of quality and of best practices.

SEE ALSO: Ancient Mortars and Plasters; Conservation; Cultural Resources Management; Deterioration of Earthen Building Materials; Polymers in Conservation; Preventive Conservation in Archaeological Sites

REFERENCES

Alva, Alejandro, and Giacomo Chiari. 1995. "Protection and Conservation of Excavated Structures of Mudbrick." In *Conservation on Archaeological Excavations, with Particular Reference to the Mediterranean Area*, edited by N. P. Stanley-Price and ICCROM, 101–12. Rome: ICCROM.

Correia, Mariana. 2016. *Conservation in Earthen Heritage: Assessment and Significance of Failure, Criteria, Conservation Theory and Strategies*. Cambridge, UK: Cambridge Scholars Publishing.

Correia, Mariana, and Maria Fernandes. 2006. "The Conservation of Earth Architecture: The Contribution of Brandi's Theory." In *Proceedings: International Seminar Theory and Practice in Conservation, a Tribute to Cesare Brandi*, edited by the National Laboratory of Civil Engineering, 233–41, Lisbon, May 4–5. Lisbon: LNEC.

Correia, Mariana, Luis Guerrero, and Anthony Crosby. 2015. "Technical Strategies for Conservation of Earthen Archaeological Architecture." *Conservation and Management of Archaeological Sites* 17 (3): 224–56. DOI:10.1080/13505033.2015.1129799.

Gandreau, David, and Chamsai Sadozai, eds. 2014. "Conservation of Earthen Architecture on Archaeological Sites: New Practices and Perspectives." In *Proceedings of the International Scientific Workshop*, May 26–28. Grenoble: CRAterre-ENSAG.

Guerrero, Luis. 2015. "Sostenibilidad y Conservación del Patrimonio Edificado." *Revista Palapa* 3 (1): 73–84.

Guerrero, Luis, Mariana Correia, and Hubert Guillaud. 2012. "Conservación del Patrimonio Arqueológico Construido con Tierra en Iberoamérica." *Apuntes* 25 (2): 210–25.

Matero, Frank, and Claudia Cancino. 2000. "The Conservation of Earthen Archaeological Heritage: An Assessment of Recent Trends." In *Postprints TERRA 2000,* edited by Plymouth School of Architecture, English Heritage, and ICOMOS/UK, 11–21, May 11–13, Torquay. London: James & James.

Mileto, C., and F. Vegas, eds. 2014. *La Restauración de la Tapia en la Peninsula Ibérica: Criterios, Técnicas, Resultados y Perspectivas*. Lisbon: Argumentum & TC Cuadernos.

Oliver, Anne. 2008. "Modified Earthen Materials." In Avrami, Guillaud, and Hardy, 97–107. Los Angeles: Getty Conservation Institute.

Warren, John. 1999. *Conservation of Earth Structures*. Oxford: Elsevier Butterworth-Heinemann.

FURTHER READING

Avrami, Erica, Hubert Guillaud, and Mary Hardy, eds. 2008. *Terra Literature Review: An Overview of Research in Earthen Architecture Conservation*. Los Angeles: Getty Conservation Institute.