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Chapter 1 Earthen architecture on archaeological sites: Sustainability principles vs decay processes

conservation of organic material is extremely good and mudbricks exist by the million. Yet very little has been done to develop independent techniques to analyze the use of molds, as striations or ridges on the brick due to unmolding. These are the features that Baudouin in this volume sees on plano-convex bricks, leading him to consider them mold-made, in opposition to the common appreciation that such a shape is indicative of hand-fashioned bricks. Another alternative has been proposed elsewhere, suggesting that standard-size rectangular bricks could be made in holes instead of wooden molds (Daneels, A. and Piña, J.S., 2019, 'Adobes prehispánicos fabricados en hoyo: un caso de la costa del Golfo de México' in del Cuero Ruiz-Funes, J.I., Méndez Pineda, V.M. and Huerta, S. (eds.), Tercer Congreso Internacional Hispanoamericano de Historia de la Construcción, Volumen I. Madrid: Instituto Juan de Herrera, pp. 267-276).

As the volume shows, typological analysis of architecture and of building materials are still the basic tools, but analytical techniques are plenty. As they are slow and expensive, some more than others, they are mostly only applied as part of long-term and well-financed projects; thus, building up databases will take time. The results achieved so far demonstrate they allow far-reaching anthropological interpretation of building traditions and cultures. Some are more recurrent (XRF, XRD, SEM, some FT-IR, mechanical properties, paleobotanical analysis of imprints and anthracology); the micromorphological analysis of construction material and rubble is on the rise, as it may well become the best way to distinguish between building techniques, by defining the features indicative of the amount of water in the mix and the degree and direction of compaction (Agnès Courty, Cécilia Cammas and Julia Wattez in France and Richard I. Macphail in England are pioneers in this respect). Other techniques, as GC-MS combined with IRMS, to identify residues of possible organic additives, are more rarely applied, because of the laboratory requirements and costs, and the difficulty to distinguish between natural and intentional residues, but such additives are part of the strategies to stabilize earthen architecture and their presence is therefore culturally significant.

As research teams working on archaeological earthen architecture increase in several countries, continued networking will be important. Several websites are already functioning, Réseau Terre (mostly archaeologists of the French speaking sphere), PROTERRA (including mostly architects and engineers but also some archaeologists of the Iberoamerican realm), while CRATerre and the Getty Conservation Institute have ongoing projects in heritage architecture preservation. Congresses specialized in earthen building and conservation, but that include archaeological research on the topic (though to a lesser extent) are the TERRA, organized by ICOMOS, UNESCO and CRATerre, Earth USA, SIACOT (Seminario Iberoamericano de Arquitectura y Construcción con Tierra), organized by PROTERRA, and the CIATTI by the Universidad de Valencia. Nevertheless, stronger interaction will be needed from archaeologists, so that a Scientific Committee specialized on Earthen Architecture could be warranted, as part of the UISPP domain of Technology and Economics. This was discussed at the symposium and remains as a proposal to be formalized in the 2020 UISPP at Meknès, Marocco, home to a distinguished earthen architecture tradition.

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Abstract

This article highlights the sustainability of earthen architecture as revealed by many archeological sites. Despite millennia of slow deterioration processes, remarkably well-preserved sites have become sources of information and inspiration for contemporary designers because of the sustainability principles they reveal. The present quest for more sustainable ways of building will not find answers in sophisticated building techniques, but rather in what our ancestors have kept doing for centuries: building simply with the resources at hand, such as earth. But this requires close collaboration between archeologists and architects to bridge the 11 000 years gap that separate us from the first builders, from whom we can actually learn much.

KEYWORDS: EARTHEN CONSTRUCTION, DURABILITY, DEGRADATION, CONSERVATION, SITE PRESENTATION

Résumé

Cet article met en évidence la durabilité des architectures de terre révélée par de nombreux sites archéologiques. Malgré des millénaires de processus de détérioration lente, des sites remarquablement bien préservés sont devenus des sources d'informations et d'inspiration pour les concepteurs contemporains en raison des principes de durabilité qu'ils révèlent. La recherche actuelle de moyens de construction plus durables coïncide entièrement avec ce que nos ancêtres ont toujours fait: construire simplement et avec les ressources disponibles, comme le permet la terre crue. Pour cela, il est nécessaire d'établir une étroite collaboration entre archéologues et architectes pour combler le fossé des 11 000 ans qui nous sépare des premiers constructeurs, dont nous pouvons réellement beaucoup nous inspirer.

MOTS-CLÉS: CONSTRUCTION EN TERRE, DURABILITÉ, DÉGRADATION, CONSERVATION, MISE EN VALEUR DU SITE

1 Introduction

From their emergence at least eleven millennia ago to contemporary times, the diverse constructive cultures associated with earthen materials have continuously spread throughout the world (fig. 1). As a result, archaeological sites presenting earth as a building material for walls, floors or roofs, are innumerable.



Fig 1. Timeline of earthen architecture testimonies © Inclusit Design 2016

Some pre / protohistoric sites, still remarkably well preserved, provide the proof that earthen construction can be perfectly sustainable under certain conditions. But in many cases, with the departure of the inhabitants who maintained them, processes of degradation began which gradually led to their ruin and sometimes even their almost total disappearance (Gandreau, 2017, pp. 23-30).

Through several examples of Near and Middle Eastern, Mediterranean and Egyptian sites built with earth, this article aims to highlight some long-lasting principles of sustainability of earthen architecture, while underlining the circumstances and processes of decay that threaten them in archaeological context.

2 Question of definition

“Clay”, “mud”, “earth”, “soil”, “pisé”, these terms are often used by archaeologists to characterize the structures they excavate. In fact, five principal modes of implementation, namely wattle and daub, cob, mud brick, rammed earth, and earth renders come in many variations, which are not always easy to distinguish in archaeological context (Houben and Guillaud, 1989; Fontaine and Anger, 2009). To avoid any semantic confusion, we define these main techniques as follow:

- Wattle and Daub. The building skeleton is made of wood and filled up with a woven lattice of wooden strips, then covered by an earthen mix on each side (fig. 2). Examples of this technique, made of reed instead of wood, are supposed to be the earliest human constructions. The site of Dikili Tash in Greece has evidences of wattle and daub from the Neolithic period (fifth millennium BCE).

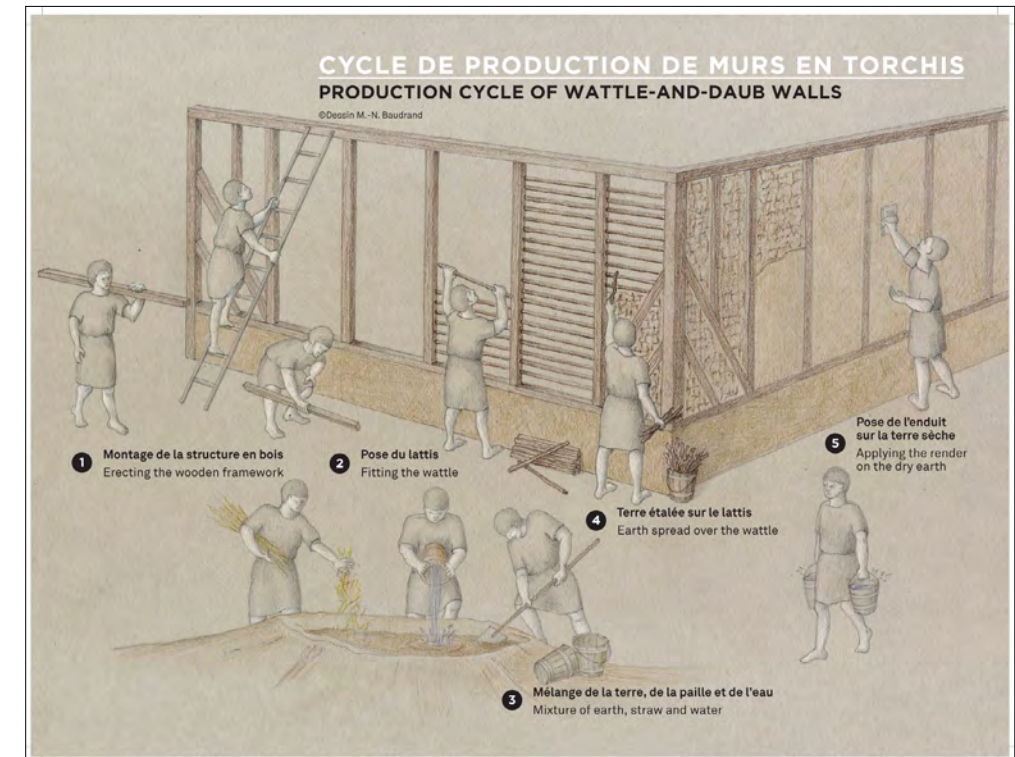


Fig 2. Wattle and daub process © M.-N. Baudrand 2016

- Cob. A wet earthen mix is laid directly on the floor in thick successive layers and the sides are cut to shape a wall (fig. 3). The wall is load-bearing by itself like a monolith. This technique can be compared to hand molded pottery with coils. Examples of cob dwellings are known in Armenia since the Neolithic period (sixth millennium BCE), in the Ararat plain (Aknashen-Khaturnakh).

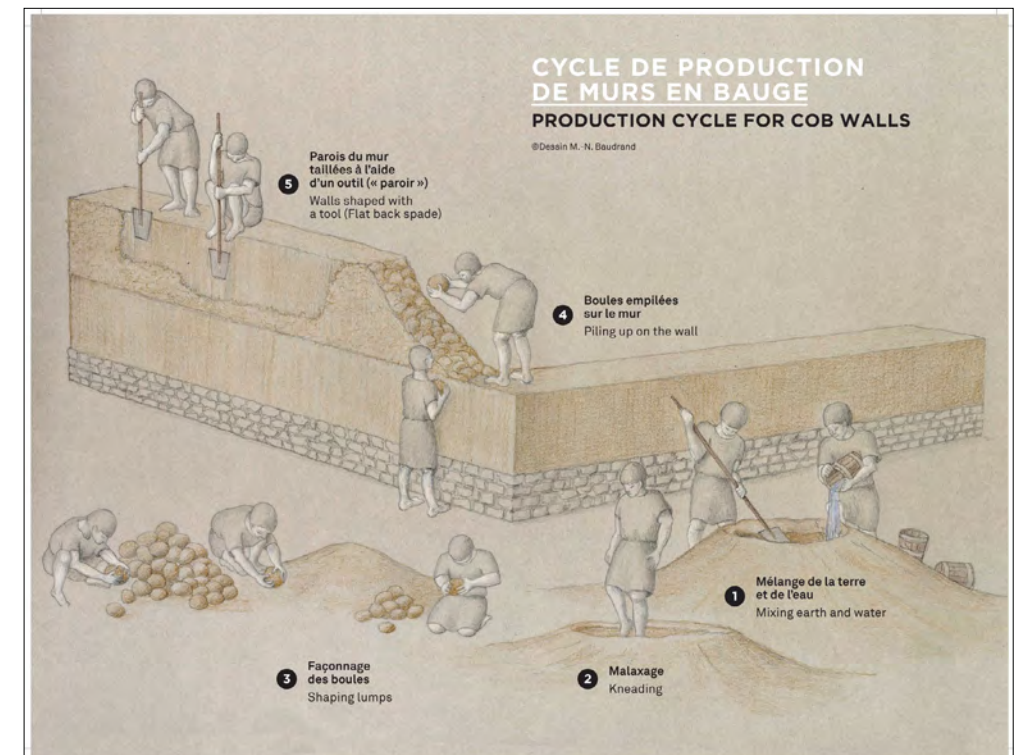


Fig 3. Cob process © M.-N. Baudrand 2016

3 Sustainability principles

The principles of sustainability were certainly not a topic of discussion 11 000 years ago. Yet the architectures that archaeological sites teach us are real lessons of sustainability for many reasons.

The first lesson of sustainability is respect for nature. These architectures have passed through the centuries without leaving any pollution behind them, because they are made of natural materials that the construction sites provided. Earth for example was used raw; it was rarely burnt, which saved energy and ensured an impact-free return of materials to the ground.

The availability of the material, in a huge quantity with minimum transport costs, exactly under the feet of the builders, allowed the inhabitants of the past to conceive towns for several thousand people. The concept of city was born, with its large-scale vision, and was replicated for many generations thanks to the reversibility of the earthen material. The vertical stratigraphy, the fact that several occupation horizons are one on top of the other during centuries, was possible because it was easy to destroy and level old phases and re-use the same building material for the next, as it did not lose its properties. Many examples of piled-up cities are known, such as Suse in Iran which was occupied from the fifth millennium BCE until the fifteenth century CE (Amiet, 1988). On a smaller scale, Ulug Depe in Turkmenistan is the only site in the region with a continuous occupation from the Chalcolithic period until the end of the Iron Age (Lecomte et al., 2002), with more than 35 m of archaeological levels.

Another remarkable feature that is sometimes possible to appreciate for several millennia after the construction is the bioclimatic quality of these architectures, which avoid extreme heat or cold. The thermal inertia properties of the earth allow a slow restitution of the temperature within the walls if they are homogeneous and thick enough. Combined with a proper orientation, an adequate location on the site, and an appropriate ventilation system, these features provided comfort despite of the absence of active heating/cooling devices.

Another characteristic is the sobriety of the means mobilised. Building was done with simple tools (hoes, wooden molds) with the only energy sources available: human (and sometimes animal) for the preparation and implementation of materials and solar for drying them. This did not prevent the production of remarkable masterpieces in terms of architectural quality and decoration. Many monumental buildings are attested, such as palaces, temples, even pyramids. Indeed, a massive ziggurat was discovered in Tchoga Zanbil for the Elamite period (third millennium BCE) in Iran, comparable to the stone pyramids of Egypt. Another noticeable building is the Great Kyz Kala in Merv, in Turkmenistan, which is supposed to be a fortified house with gigantic crenulations all built in mudbricks. This building crossed the centuries and still stands up 12 m above the ground on the Bactriana plain (fig. 7).

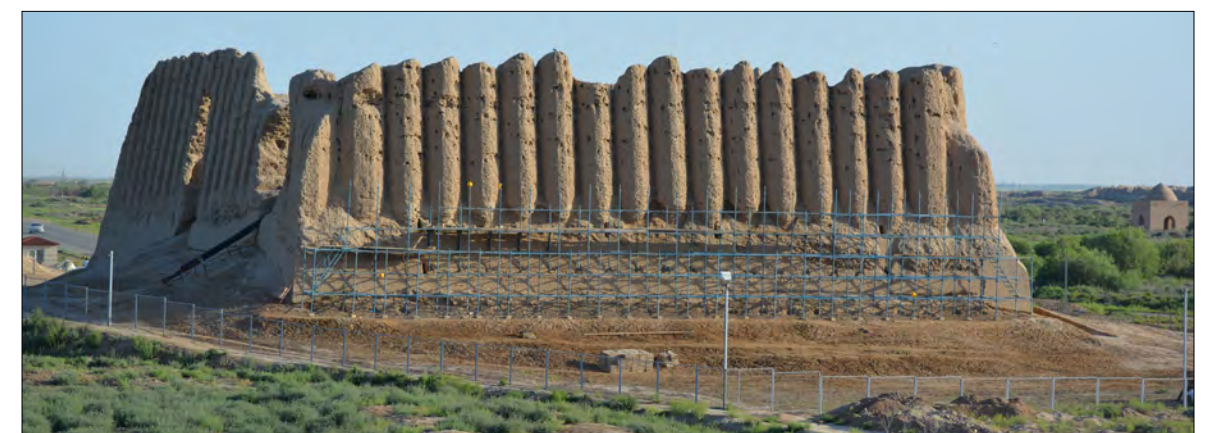


Figure 7. The Great Kyz Kala in Ancient Merv (Turkmenistan) ©CRAterre_D. Gandreau 2015

- Adobe or mudbrick. A wet earthen mix is molded and sun dried to create small standard elements easy to handle (fig. 4). It has been the most widespread building system in the world for centuries. The best-known example is coming from Pre-Pottery Neolithic A (eighth millennium BCE) of the famous site of Jericho (Tell es-Sultan).

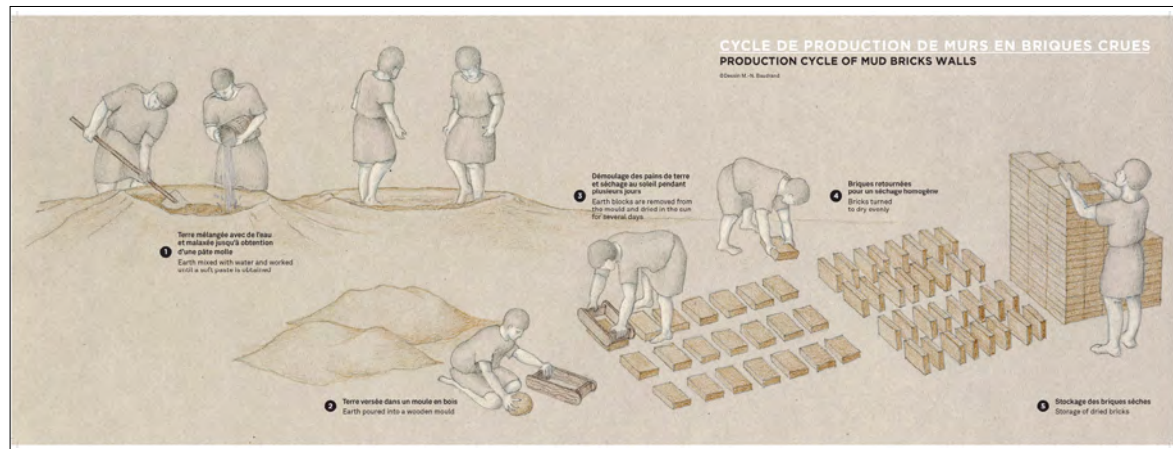


Fig 4. Mudbrick process © M.-N. Baudrand 2016

- Rammed earth. Earth is compacted in a very low humid state between two pieces of wood (fig. 5). Like cob walls, rammed earth walls are monolithic. Early evidences are scarce but some examples can be found in China.

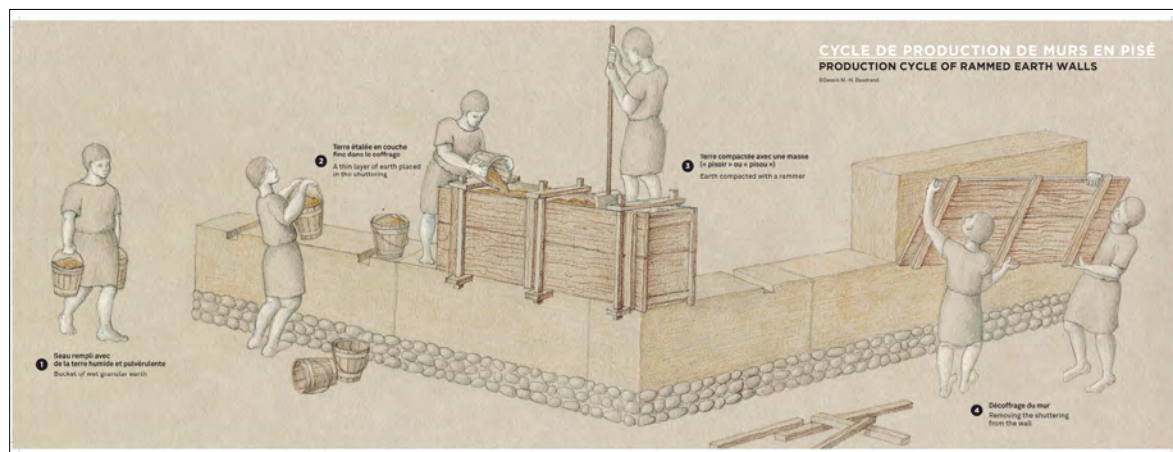


Fig 5. Rammed earth process © M.-N. Baudrand 2016

- Renders. Thin coats of earth preparation are applied on a vertical surface and can receive any type of decoration (fig. 6). Examples in Djade al-Mughara in Syria are attested since the ninth millennium BCE.



Figure 6. Mural painting of Djade el Mughara. © Mission archéologique de Dja'de, E. Coqueugnot

Because of the simplicity of the materials and the means of implementation, these architectures were easy to maintain with the same resources and know-how. As a result, they ensured the resilience of their inhabitants/self-builders who carried out the entire construction process, without relying on outside resources. The earthen architecture and masonry skills those people mastered are impressive lessons for us. Even in villages such as Hili 2 in the United Arab Emirates, where there is no urban settlement comparable to those of Mesopotamia, the houses of common people are still visible today, 3000 years after they erected them, from the floor to almost the ceiling 2 m above the ground. The community decided to build with thin layers of cob stabilized by thin mud bricks on top of each ring, and we still don't understand the reason for it. Another example is the Ramses granaries in Egypt, called the Ramasseum, where long and narrow rooms vaulted with mudbricks are still visible today.

Let's not forget the cultural richness of the first architectures. The simplicity of the tools and materials described above have not hindered creativity. The diversity of archaeological remains that excavations have revealed are evidence of human genius to design rich and varied cultures.

4 Decay processes

Archaeology has revealed the full potential of earthen architecture, but unfortunately it is also participating to its loss. Indeed, two phases of decay are visible on the lifespan of earthen archaeological remains. The first one occurs when the inhabitants abandon the building, and the second one, faster, is happening after the discovery and excavations by archaeologists.

After their abandonment, all earthen buildings, regardless of the technique employed, slowly enter in a decay phase related to erosion processes. Usually, people take away reusable and precious materials such as wooden beams or stones. Absence of roof and hard material in critical points (gutter, lintel, threshold), combined to the lack of maintenance, makes the building vulnerable to wind and water deterioration (stagnation, rain, dampness), sometimes animals squat (nest, burrow, detachment on the top). Slowly but surely, soft parts are losing cohesion and sharp features are worn away creating a big mound in the landscape. After this slow-motion process, the decaying phase is over, the mound is stabilized and the buried elements easily survive for centuries, including precious decorated surfaces (fig. 8).

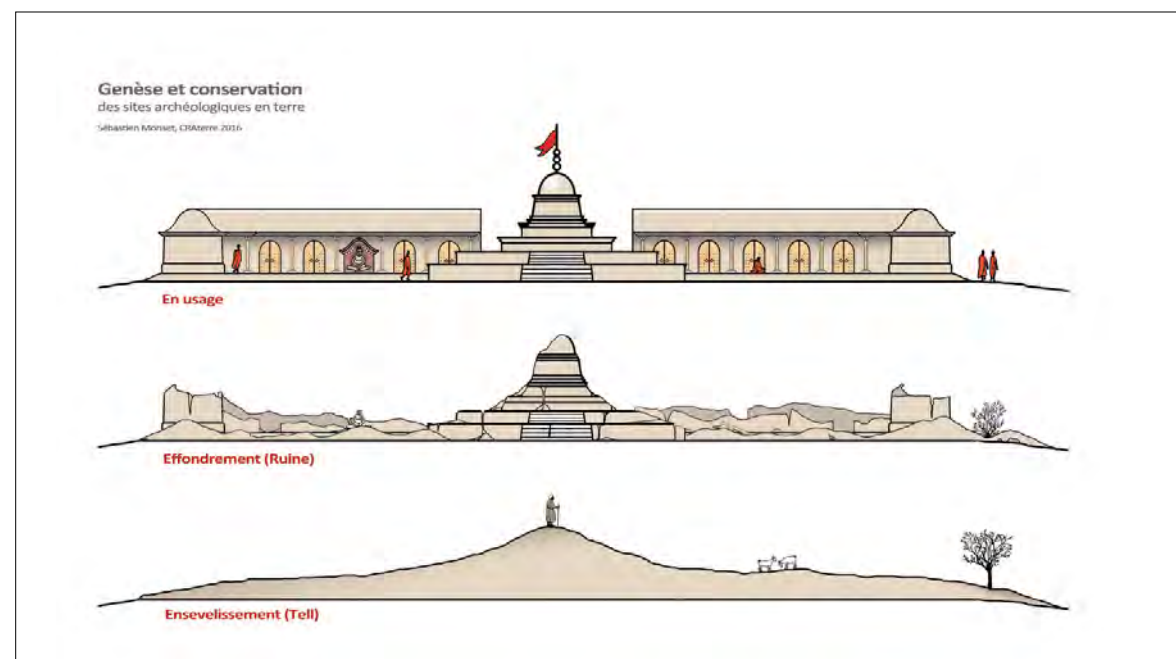


Figure 8. Decay processes after abandonment ©CRAterre_S. Moriset 2016

When archaeologists discover a mound created by anthropic activity (also called a tepe or a tell in Middle East), a new cycle of accelerated decay is starting. Trenches are opened, walls are left exposed without roofs and trenches are dug with no way out for drainage (fig. 9).



Figure 9. Open trench in Mary (Syria) left without any conservation measure ©CRAterre_M. Bendakir

When it is raining, water is pooling and walls are acting like sponges, absorbing all the dampness by capillarity. As a consequence, wall bases are damaged creating a weakness. This is a very common pathology, characterized by a wall profile looking like an apple core also called “undercut” or “coving” (fig. 10).



Figure 10. Undercut pathology in Ancient Merv (Turkmenistan) ©CRAterre_C. Sadozai 2015

Other structural pathologies are observed after a long exposure without preventive conservation measures. Vertical cracks and leaning walls can, as well as the undercut, threaten the whole building's stability and can lead to a collapse. Superficial clues of degradation can also warn about the integrity of the building, such as minor cracks, material detachment or loss, and gullies (Sadozai, 2013).

Until recent times, inefficient conservation measures taken after the excavations revealed also, in some cases, major disturbances. The use of inappropriate protective materials or shelters without regular monitoring sometimes creates more damages than doing nothing (Daneels and Guerrero Baca, 2015).

5 Learning from earthen archaeological sites

5.1 Conservation

Understanding the decay processes is a key to better preserve earthen structures and possibly preserve them to future generations. Close observation of pathologies on the building and its surroundings is required to achieve a precise diagnosis (Gandreau and Sadozaï, 2015). The conservation principles applied to earthen archaeological remains are well-known and are based on common sense, for example do not allow water to stagnate near the structures and impregnate the walls by capillarity, or do not leave fragile elevations exposed to wind, rain and frost without protection.

This sounds simple, but preserving an excavated site is a great challenge and can hardly be achieved once the remains are exposed. Conservation strategies need to be integrated in the archaeological campaigns, with time, financial resources and knowledgeable experts entirely dedicated to the task. Conservators should work alongside with archaeologists to apply the appropriate emergency measures required to stabilize the whole excavated sector until all the stakeholders agree upon a holistic strategy (Sadozaï and Gandreau, 2016).

In theory, for any new archaeological project a conservation strategy must be thought out before starting. Many governmental authorities have understood this today and ask for realistic conservation plans to be presented before issuing excavation permits. Several archaeologists have been denied the right to dig because they could not meet the required conservation guarantees. The conservation program can of course vary depending on the findings, but it helps at least to determine in a specific time frame the appropriate conservation techniques to use, as well as the roles and responsibilities of each partner.

5.2 Contemporary architecture

Does it make sense to oppose these thousand years old ruined architectures versus contemporary ones? It is a trend for architects today to reconnect their contemporary production to the vernacular architecture of the region where they build. This seems logical today in a context where it has become essential to save resources by reducing the transformation and distribution circuits of building materials by using locally sourced materials and relying on the human resources of the place. This is exactly what our ancestors tried to achieve for several millennia. What we see as outdated productions of the past often appear to be extraordinary sources of inspiration for today's architects. The idea is not to duplicate ancient models, but to draw inspiration from various parameters. Which type of soil was used for which building parts? How was the soil processed and turned into buildings parts? Which tools and social organization allowed achieving building so simply and so fast? What features guaranteed thermal comfort in the absence of electricity? Many more questions can be asked. A European Union funded research programme called VERSUS (www.esg.pt/versus) listed in 2014 all the lessons that can be drawn from vernacular architecture to explore new ways to design contemporary sustainable buildings (Guillaud et al., 2014). It provides a methodology for scholars, students and professionals to easily draw the lessons from past architectures, regardless of their age, that can be reused in a contemporary way (Sanchez et al., 2018).

On an archaeological site, the link between ancient and contemporary architecture can easily be done through a site presentation strategy that requires erecting new buildings. The necessity of

exhibiting artefacts in situ in a visitors' centre for example offers the possibility of building a contemporary structure with modern features inspired by ancient techniques. The project of Mari in Syria is a good example of a site museum built in earth with modern features (fig. 11).



Figure 11. Mari Visitors' center (Syria) ©CRAterre_M. Bendakir 2010

6 Conclusion

The archaeological remains of earthen constructions are rarely considered by contemporary builders as sources of information that could guide their practice. The fragility that the ruins show us immediately destroys the idea that these architectures bear lessons that have remained relevant over the millennia. However, conservation has brought many archaeologists closer to architects who are committed to contemporary issues of sustainable development, for whom the use of eco-responsible materials such as earth is obvious. The dialogue between archaeologists and architects has connected very old buildings to contemporary productions, around similar materials and techniques, simply facilitated by the tools available today. The extraordinary state of conservation of certain earthen architectures with elevations of several meters, after millennia of slow decay, proves the durability of this material, and its ability to respond to the principles of sustainability. Most of the solutions are in the past, it is for us to dig them up, revitalize them and adapt them to our contemporary needs, creating a connection between those who understand the past (archaeologists) to those who design the future (architects).

Chapter 2 Spread and Independent Technical Invention of the Earthen Material

In the Southern Caucasus and Northern Mesopotamia during the sixth Millennium BCE

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Abstract

The existence of relationships between Southern Caucasus and Northern Mesopotamian communities was inferred since the 1960's. Since 2008, international archaeological teams have focused on the Southern Caucasus in order to verify these hypotheses and understand the "neolithisation process" on the periphery of the Near East. Here I will focus on the evolution of cob and mud-brick. An evolution of these earthen material techniques during the sixth millennium BCE is proposed by means of a re-examination of stratigraphic contexts, bibliographical data and also by recent discoveries in these regions. The spread of cob could be traced across Northern Mesopotamia since the end of the seventh millennium BCE, and then towards Eastern Anatolia and Southern Caucasus during the sixth millennium BCE. Simultaneously, the molded plano-convex mud-brick appeared in the Shulaveri-Shomu culture in the sixth millennium BCE. This special technique seems to be a local and independent innovation, according to other architectural characteristics.

KEYWORDS: NEOLITHIC, EARTHEN ARCHITECTURE, SUN-DRIED MUD-BRICK, COB

Résumé

Les relations culturelles entre les communautés du Caucase et celles de Mésopotamie du Nord sont attestées depuis les années 1960. La reprise récente des investigations dans le Caucase a pour ambition de comprendre le processus de néolithisation en marge du développement des communautés mésopotamiennes. Je concentrerai mon propos sur l'évolution de la bauge et de la brique crue. Une évolution de ces techniques de construction au sixième millénaire AEC peut être proposée par une révision de la stratigraphie, de la bibliographie et par l'apport de données inédites. La question de la diffusion de la bauge au septième millénaire, du Nord de la Mésopotamie vers l'Anatolie orientale et le sud du Caucase durant le millénaire suivant, peut être posée, alors qu'en même temps, dans la culture de Shulaveri-Shomu, apparaît la brique crue moulée plano-convexe. Cette technique particulière semble y être une innovation locale et indépendante, hypothèse confortée par d'autres éléments architecturaux.

MOTS-CLÉS: NÉOLITHIQUE, ARCHITECTURE EN TERRE, BRIQUE CRUE, BAUGE

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