

EARTHEN ARCHITECTURES: HISTORY, TYPOLOGIES AND CONSTRUCTION TECHNIQUES

*Original*

EARTHEN ARCHITECTURES: HISTORY, TYPOLOGIES AND CONSTRUCTION TECHNIQUES / Mattone, Manuela. - STAMPA. - EARTHEN ARCHITECTURES: HISTORY, TYPOLOGIES AND CONSTRUCTION TECHNIQUES:(2021), pp. 11-22.

*Availability:*

This version is available at: 11583/2934152 since: 2021-10-24T08:34:24Z

*Publisher:*

CNR Edizioni

*Published*

DOI:

*Terms of use:*

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# PAST AND PRESENT OF THE EARTHEN ARCHITECTURES IN CHINA AND ITALY



Edited by  
Loredana Luvidi, Fabio Fratini  
Silvia Rescic, Jinfeng Zhang



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EDITED BY  
LOREDANA LUVIDI, FABIO FRATINI  
SILVIA RESCIC AND JINFENG ZHANG

This series of volumes comprises research outputs that have been achieved due to the financial contribution of the National Research Council of Italy (CNR) and the the Chinese Academy of Cultural Heritage (CACH) within the context of a Bilateral Agreement of Scientific and Technological Cooperation between these two Institutions.

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P.le Aldo Moro 7  
00185 Roma

ISBN paper version        978 88 8080 470 3  
ISBN electronic version    978 88 8080 315 7

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1. TECLA (Technology and Clay) 3D printed house by WASP and Mario Cucinella Architects, Massa Lombarda, Ravenna, ITALY (2021)
2. Ruins of a vernacular building in Sant’Omero, Abruzzo, ITALY (by Dalila Fortunato and Anna Jaroszewski, 2020)
3. Ruins of Gaochang ancient city, Xinjiang Province, CHINA (by Fabio Fratini and Loredana Luvidi, 2016)
4. Kezi ergaha beacon tower (Han Dynasty) in Kuche city, Xinjiang province, CHINA (by Center of Conservation of Xinjiang Cultural Heritage, 2020)

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# FOREWORD

GILBERTO CORBELLINI

*Director, Department of Social and Human Sciences, Cultural Heritage, National Research of Science of Italy - CNR*

In 2015 CNR and CACH initiated their collaboration, which introduced, next to the bilateral research project programs, also a book series on China and Italy. This volume is the fourth publication in this series.

The research carried out within this bilateral project and discussed in the contributions of this book deals with the conservation of earthen architecture, widespread in many regions of China and Italy, as well as in other countries of the world. These buildings represent a very perishable cultural heritage due to the low durability of earthen artefacts towards atmospheric agents. Therefore, their existence is in danger because it is difficult to consolidate the earth without causing further damage to the original material.

In China, earthen artefacts comprise wall structures, whole cities and monumental or historic buildings of great value. Their characteristics differ from one territory to another, in relation to the geographical context in which are located and the cultural environment. There is also a diffused vernacular architecture of lesser value that gives character to each territory making it different from any other, but at serious risk of disappearance. Urbanization and the aspiration of people to conditions of better comfort has meant that the countryside has become depopulated with the abandonment of houses that are disappearing without maintenance.

The collaborative work between CACH and CNR researchers aimed at identifying products and methods suitable for the conservation of the earthen material which characterize this architecture. The earthen architecture of Italy is different from the Chinese one and generally present in vernacular heritage. It is a little-known cultural asset but through its study it will be possible to enhance and preserve this architecture which testifies to the wealth of technological-cultural diversity of man's housing adaptations to changing environmental contexts.

The challenges faced by the CACH - CNR joint research project have been and are an important scientific growth ground for ISPC, the CNR Institute dedicated to the study of the conservation and enhancement of cultural heritage in a multi- and interdisciplinary perspective.

Scientific methods and new technologies are now used to improve the understanding of building technologies, conservation aspects and enhancement of this architectural heritage, whose knowledge for a long time was based only on historical and socio-anthropological studies.

CHAI XIAOMING

*Director General, Chinese Academy of Cultural Heritage – CACH*

Based on the bilateral cooperation framework between CACH and CNR, five selected projects have been initiated and launched in 2016. To show and exchange the achievements of cooperation, both sides plan to jointly edit a series of academic publications. This book, I am glad to see it as the fourth collection of papers growing out of the bilateral cooperation, includes papers on both sides' achievements in researches of history, existing status, conservation and perspectives in earth architectures in China and Italy.

Earthen sites is one of earliest kind of human remains. They show not only our past, but also future. Through the bilateral cooperation, as shown by the papers in the book, refreshing and inspiring light have been shed on complex issues concerning conservation and valorization of earthen sites, the theme of which indeed deserves academic comparison from multi-cultural perspectives to comprehend the evolution of research, conservation and management under different social contexts.

As much as I am pleased to see the book, I look forward to continuing and deepening this kind of bilateral exchanges with more and more fruits growing out of it. Therefore, CACH would like to further our cooperation with CNR and provide all necessary support, to strengthen and advance conservation communication, and cultures behind.



## INTRODUCTION

FABIO FRATINI<sup>1</sup>, LOREDANA LUVIDI<sup>2</sup>, SILVIA RESCIC<sup>3</sup>, JINFENG ZHANG<sup>4</sup>

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The National Research Council of Italy (CNR) and the Chinese Academy of Cultural Heritage (CACH) during the past three years (2016-2018) carried out a Joint Research Project on “Assessment of innovative methods for the conservation of earthen surface”. The project was carried out by the Institute for the Conservation and Valorization of Cultural Heritage (ICVBC) of the CNR that since 1st October 2019 was suppressed to join the new Institute of Heritage Science (ISPC-CNR). The ISPC deals with the study of the conservation and enhancement of cultural heritage with a multidisciplinary approach, which take advantage of scientific methods and new technologies together with historical and social aspects.

The subject of this Joint Research Project was a real challenge and continues to be so. Actually if the decay of building stone materials exposed to the external environment still represents one of the main threats to monuments and architecture all over the world, a fragile architecture such as the earthen one, is in a situation of increased risk considering the climate change problem and the increased rainfall intensity.

Earthen architecture is a type of construction almost unknown to most of the inhabitants of the developed countries and when it is talked about it, is most often in a derogatory way (i.e. “poor mud houses”). Actually, the earthen constructions are spread in many countries and constitute a testimony of skills and habits of peasant civilizations. Earth is one of the oldest materials used in architecture. It was widely used in ancient Egypt and in the civilizations of Mesopotamia and it is mentioned in the Bible (Book of Exodus 5, 6-8). The constructions of Iran, Afghanistan, Yemen, Iraq, Morocco and Mali testify that earthen architecture has evolved and specialized until reaching a remarkable technical perfection (vaulted systems, domes, multi-storey buildings, decorated surfaces). About 30% of the world population lives in earthen buildings.

Earthen buildings are present also in Europe: Germany, United Kingdom, Spain, Portugal, Poland, Hungary, Romania, Baltic countries. In France 15% of the rural population lives in earthen buildings. In Italy, earthen architecture is present in Sicily,

Sardinia, Calabria, Basilicata, Abruzzo, Marche, Tuscany and Piedmont. Similarly, throughout the western part of China, along the Silk Road, earth is the most widespread building material, both in civil and monumental architecture and in fortifications. It is therefore a type of architecture that for good reason constitutes an important cultural heritage, both from a material and immaterial point of view due to the social implications relating to the construction of the buildings which often involves entire communities.

For some decades, however, we have witnessed the gradual abandonment of earthen buildings, because they are considered unhealthy and unsafe, incompatible with the modernity that people are looking for. In addition, there are three other aspects that hinder the use of earth: it is a material whose application requires specific knowledge and skills; it is a fragile architecture that requires scheduled maintenance which, if it fails, leads to decay; modern building standards are still very restrictive and do not favour the use of earth in architecture.

For all these reasons, preserving earthen architecture and ensuring its existence over time is a real challenge. Experiments are needed to identify the means by which to improve its resilience, so as to foster both the preservation of the existing earthen heritage and a more widespread use of earth in new constructions.

This book, in addition to contributing to the dissemination of knowledge of earth architecture in China and Italy, examines the conservation techniques used in the respective countries and the researches that are being carried out to improve these interventions in order to make them more durable and compatible with a material as delicate as earth. The new opportunities that the earth architecture can have in future in the two countries are also illustrated.

Ultimately, this book is an attempt to bridge the gap between the science applied to Cultural Heritage and the real meaning of the so-called "cultural asset".

Cultural heritage is the result of sensitivity, thought, expectations and skill of men and women stratified over the centuries who, with their identities and personalities, have built the reality in which we live today and with the help of science we want to contribute to its preservation.

**PART 1**

**HISTORICAL USE OF EARTHEN MATERIALS FOR  
ARCHITECTURE**



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# EARTHEN ARCHITECTURES: HISTORY, TYPOLOGIES AND CONSTRUCTION TECHNIQUES

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**Keywords:** Earthen buildings, construction techniques, typologies

## INTRODUCTION

Earthen architectures are ones of the best evidence of the human capacity to create built environments adopting locally available resources. Earth is a versatile material, used since ancient times for the construction of architectural artefacts independently or associated with other materials such as stone, wood, gypsum, lime, vegetable fibers. Although today, earthen constructions are widely perceived as “mud huts”, associated with an image of poverty and social and cultural marginalization, their significance and potential are known and recognised. Many of the oldest buildings in the world have been built with earth; at least one quarter of the world’s population lives in earthen dwellings and in more than 180 sites of the UNESCO World Heritage List incorporated earthen elements (Joffroy et al., 2017, p. 15). As the Lyon declaration<sup>1</sup> states, “earth has been, is, and will be one of the major materials used by humankind to build its habitat and shape its environment” (Joffroy et al., 2017, p. 15).

Earthen buildings, whether monumental buildings or rural dwellings, are traceable all over the world, where the chemical-physical characteristics of the earth and the climatic conditions would allow the adoption of this material for the construction of architectural artefacts. There are many ways to use earth for construction purposes, which are expressions of the cultural identity of the different sites. Hugo Houben and Hubert Guillaud (Houben, Guillaud, 1989, 101) identified twelve ways<sup>2</sup> which can be

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1 Subscribed by all the participants to the XIIth World Conference on Earthen Architecture, Terra 2016 and published in Joffroy T. et al. eds. (2017), *Terra Lyon 2016 Proceedings*, Villefontaine (France).

2 According to Houben and Guillaud earth can be: dug out, cut, filled in, covered, compressed, shaped, stacked, moulded, extruded, poured, formed, daubed (Houben, Guillaud, 1989, p. 15).

adopted for the erection of earthen constructions, among these, seven are the most widespread. They are: *pisé* (also known as rammed earth, it is a constructive procedure that consists in "beating" - *piser* - the specially prepared earth inside a mobile wooden formwork); *bauge* (earth-straw dough adopted to shape irregular elements which, once overlapped, are regularized with the aid of a sharp blade); *torchis* (earth application on a timber support); *adobe* (construction technique that uses raw bricks, made by hand compacting, in wooden forms, a mixture of earth which are often added vegetable fibres); *earth-straw* (earth, which must be characterised by high cohesion, is dissolved in water and poured on the straw so as to cover it all); *forming* (earth is shaped by hand as if it were pottery) and *compressed block* (earthen blocks are produced using hand tools or mechanical presses so as to improve mechanical performances, thanks to the reduction of cavities and water content) (Fig. 1).



Fig. 1 Adobe rural architecture in Morocco (by M. Mattone, 2015)

Many treatises and manuals widely address the earth constructions topic. Vitruvio in the *De Architectura* indicates how to select the earth to be used for the production of bricks<sup>3</sup> and the best seasons for the construction of the buildings in order to guarantee their better durability. Plinio illustrates how to make the walls in *pisé*, underlining that "these last many summers resisting rains, winds, fires with more solidity

3 Vitruvio Pollione M. (15BC), *De Architectura*, Books X, Roma, (It. transl. Migotto L. Porde- none. Edizioni Studio Tesi, 1990), 2nd book, pp. 73-75.

than any cement wall"<sup>4</sup>. Rammed earth technique generates increasing interest at the end of the eighteenth century, when new construction systems are extensively experimented. In 1791 François Cointeraux<sup>5</sup> published his studies on rammed earth. It was translated into English, German and Italian, ensuring the spread of this construction technique across Europe. The studies, concerning earthen building techniques, are resumed again in 1802 by Jean-Baptiste Rondelet<sup>6</sup> and, later (Figg. 2-3), by Daniele Donghi<sup>7</sup> (1920) and by Gustav Adolf Breyman<sup>8</sup> (1926).

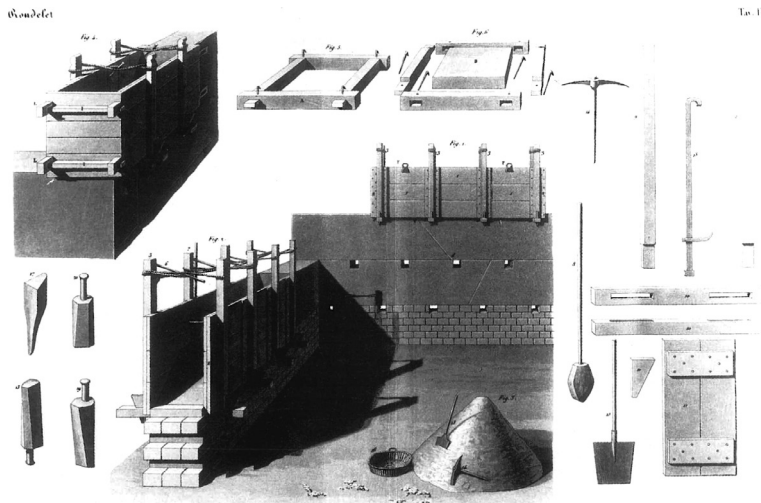


Fig. 2 Tools and methods for the construction of earthen walls in pisé (Rondelet J-B. (1860).  
 Traité théorique et pratique de l'art de bâtir. Paris. Firmin-Didot, tav. IV)

- 4 G. Plinius Secundus, *De Naturalis historia*, 77, (It. Transl. M.L. Domenichi, G. Antonelli ed., Venezia 1844), XXXV, XLIII.14.
- 5 Architect and professor of rural architecture, François Cointeraux (1740-1830), born in Lyon, publishes four small volumes illustrating the construction system he perfected himself, thanks to the experimentation of a mechanical method of great simplicity, useful for the realization of earthen walls. In *Ecole d'architecture rurale, ou Leçons par lesquelles on apprendra soi-même à bâtir solidement les maisons de plusieurs étages avec la terre seule, ou autres matériaux les plus communs et du plus vil prix*. Paris, 1791, Cointeraux explains methods and rules for the production of earthen wall, for the choice of the optimal earth and for the production and application of plasters and decorations.
- 6 Rondelet J-B. (1860). *Traité théorique et pratique de l'art de bâtir*. Paris. Firmin-Didot.
- 7 Donghi D. (1920). *Materiali, elementi costruttivi. e finimenti esterni delle fabbriche*. Torino. UTET.
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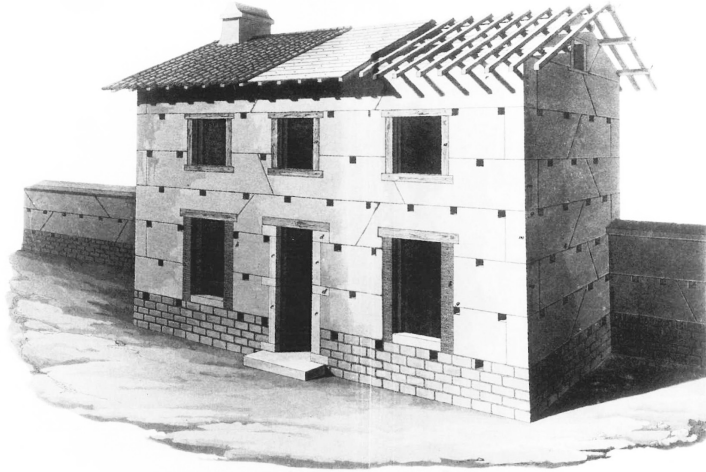


Fig. 3 Constructive features of a rammed earth building. (Rondelet J-B. (1860).  
Traité théorique et pratique de l'art de bâtir. Paris. Firmin-Didot, tav. V)

## EARTHEN CONSTRUCTIONS IN THE WORLD: monumental and vernacular architectures

The first use of earth as a building material probably comes from the need to make sheltered places, such as caves, more comfortable (Guerrero, 2007, Jaquin, Augarde, 2012). The progressive transition from a nomadic life model to a sedentary one has led to the birth of the first permanent settlements and the development of solid and durable building materials, too. "The first earthen building technique to develop is likely to have been wattle and daub: construction of a façade or roof using timber or grasses, which is covered in earth. Later a rammed earth type of technique may have been developed" (Jaquin, Augarde, 2012, p. 13), compacting earth by hand and afterwards using wooden formworks. Earthen constructions initially arose along the banks of rivers such as the Tigris, Euphrates, Nile, Indus and Huanghe, where sandy and clayey earth was normally mixed with straw resulting from the cultivation of cereals and adopted as building material. The subsequent development of single constructive elements (such as blocks) would allow, once dried, to transport them, giving the opportunity to build earthen constructions even at a certain distance from the rivers' banks (Jaquin, Augarde, 2012, pp. 13-14). Earth buildings can be found in Africa, Asia, Europe and America. Vernacular architectures, as well as monumental buildings are made using raw earth technology.



In Africa, the earliest woven reed and branch earth-covered sites date back to 5000 BC in the Nile Delta (e.g. Mermide and Fayun); the production of hand-made adobe bricks began starting from 2900 BC approximately and they were used in the construction of monumental buildings such as the large independent adobe structures at Shunetel-Zebib and Nekhen and the pyramids discovered at Tamis. Also many of the buildings built by the Pharaoh Ramsese II (1279-1213 BC), as well as the dwellings of artisans, nobles and temples were in adobe. Generally, the most modest dwellings consisted of one or more rooms whose walls were made of earth and covered with lime plasters. The rich mansions of the nobles, equipped with several rooms and spaces intended for servants, were more spacious and entirely built with earth (see, for example, the settlement of Deir el Medina). As far as North Africa is concerned, the influence exerted by different civilizations that have succeeded over time has contributed to the dissemination of both the techniques of adobe and pisé. Starting from the eleventh century, the spread of Islamic culture determines a significant change in the characteristics of urban settlements and the construction of a new type of religious buildings such as mosques. In Morocco, in the valleys of the Drâa and Dadès rivers there are hundreds of rammed earth settlements like the ksar of Aït Ben Haddan and the kasbah of Tourit in Ouarazazate (Figg. 4-6). The urban walls of Marrakech and Fes are also made of rammed earth. As for the mosques, the most significant examples can be found in Mali (such as the Great Mosque of Djenné and the Djinguereber Mosque in Timbuktu) and in the Niger (Great Mosque of Agadez). They are decorated with bundles of palm stalks that, protruding from the wall, are used as scaffold for annual maintenance interventions of the earth surfaces.



Fig. 4 Earthen settlement in Morocco (by M. Mattone, 2015)



Fig. 5 The Kasbah of Tourirt in Ouarazazate (Morocco) (by M. Mattone, 2015)



Fig. 6 Earthen building in Ouarazazate (Morocco) (by M. Mattone, 2015)

In the Near Middle East, the earth finds application in the construction of monumental buildings such as the temple cities of the Uruk period (3200-2800 BC) and the sanctuaries, erected in the third millennium BC (e.g. the temple of Euki a Eridu), made of bricks assembled without mortar. Interesting buildings can be found also in Iran. Historic adobe buildings stand in the cities of Yazd and Isfahan; rammed earthen walls surround the city of Tous; adobe structures characterised also the citadel of Bam, the largest adobe settlement in the world, unfortunately collapsed because of an earthquake in 2003. In Yemen, from the XVIII century many buildings were erected, such as the adobe minaret of the Al-Muldher Mosque which, being 53 m high, "is probably the tallest earthen structure in the world"

In the Far East, earth is widely adopted in the construction of walls, as well as residential buildings. The first defensive rammed earth walls were erected by the Qin dynasty (221-206 BC) in the plains along the northern borders in western China<sup>9</sup>. "However, it is in the Great Wall where the use of rammed earth is most recorded" (Jaquin, Augarde, Gerrard, 2008, p. 380). These walls were restored and extended by the Han dynasty (206 BC – 202 AD) and the Jin dynasty (265-420 AD), but few original sections remain (Jaquin, Augarde, Gerrard, 2008).

As far as residential buildings are concerned, the *Tu lou* (which means earthen structures) are particularly interesting examples: they are large round or square four storeys rammed earth constructions erected for defence purposes around a central open courtyard (Jaquin, Augarde, Gerrard, 2008). The presence of only one entrance and no windows at the ground floor make them easy to defend. Recently inscribed in the World Heritage List, they are "exceptional examples of a building tradition and function exemplifying a particular type of communal living and defensive organisation and, in terms of their harmonious relationship with their environment, an outstanding examples of human settlement"<sup>10</sup>.

In Europe, the construction techniques used are multiple (Guillaud, 2008; Correia, Dipasquale, Mecca, 2011). In northern Europe, mixed earth and timber structures with wattle and daub or half-timber techniques are adopted. *Cob*<sup>11</sup> structures dating back to the XVth century, have been found in the UK and this constructive technique has been used up to the XIXth century, even if the adoption of earth as a building material declined from the XVIth century because of the increasing use of fired bricks. In the South, adobe and rammed earth techniques are more common. The first buildings date back to about 5300 years ago and are located in Sesklo in Greece. These are single-storey residential buildings in torchis and dried bricks resting on a stone base. Rammed earth, which may have been brought to Europe by

9 Jaquin, Augarde, 2012, p. 16, Jaquin, Augarde, Gerrard, 2008, p. 380.

10 <https://whc.unesco.org/en/list/1113> (visited on the 12th October 2018).

11 English term used for earth walls built up without formwork.

Phoenicians (Houben, Guillaud, 1989), is widely adopted in Spain<sup>12</sup> (Mileto, Vegas, 2014, García-Soriano, Villacampa Crespo, Gómez-Patrocínio, 2018), France (Guillaud, 2008), Italy (Bertagnin, 1999; Sori, Forlani, 2000; Mattone, 2010; AA. VV., 2011), Portugal (Fernandes, Correia, 2005). City walls (e.g. the ones of Cordoba, Seville and Granada), monumental buildings (e.g. the Alhambra Palace in Granada) (Fig. 7), both urban (e.g. the historic city centre of Novi Ligure in northern Italy and of Lyon in France) and vernacular architectures (such as the rural buildings of Piemonte, Sardegna, Marche, Abruzzo, Calabria regions in Italy and of Rhône-Alpes and Auvergne regions in France) can be found in different countries (Fig. 8).



Fig. 7 The wall of the Alhambra Palace in Granada (by M. Mattone, 2017)

<sup>12</sup> In Spain, the adoption of earth as building material is already stated by Plinius who, in 77 AD, writes: "Spain still sees the watchtowers of Hannibal [who invaded Iberia in 218 BC] and turrets of earth placed on mountain ridges" (Plinius Secundus G. (77). *De Naturalis historia*, (it. Transl. M.L. Domenichi, G. Antonelli ed., Venezia 1844), XXXV, XLIII.14). Rammed earth (called Tapia) would be widely used starting from the VIII century by Muslims for the construction of military and civil architecture.



Fig. 8 Earthen vernacular architecture in Priocca (Cuneo, Italy) (by M. Mattone, 2016)

In America, earthen constructions are both in the North and in the South. In North America (Mexico and Southern United States), earth was used by native populations. The Aztecs built their monumental architectures in stones, while vernacular buildings were built in adobe. The latter were also used by Europeans coming to North America for the construction of missions and frontier forts such as Tomacacori, Guevavi and Calabazas Jesuit missions in Arizona (1691). Later, in the middle of the XIX century, the US army also adopted the adobe technique to build Fort Union and Fort Selden. As for the rammed earth technique, it was brought to the American country by German immigrants. Rammed earth constructions can be found in Washington (Hilltop House), at Mount Vernon, in Trenton (New Jersey), in Canada (St Thomas Church in Shanty Bay and residential buildings in Greenville).

In South America archaeological evidence of earthen buildings can be found in the coastal regions of Peru. First proof of the use of raw bricks is related to Moche culture, which developed in northern Peru between the II<sup>nd</sup> century and the IX<sup>th</sup> century. In the city of Cerro Blanco, two pyramids, dedicated to the sun and the moon, were built. They are adobe core pyramids almost 50 m tall. After the decline of the Moche culture the largest civilisation to develop was the Chimú. Chan Chan was the capital of the Chimú culture. In 1875 the archaeologist Ephraim George Squier described

Chan Chan as "the most extensive and populous of all the cities of ancient Peru". It consists of "long lines of massive walls, gigantic chambered pyramids, or *huacas*, remains of palaces, dwellings, aqueducts, reservoirs, granaries, prisons, furnaces, foundries, and tombs, extending for many miles in every direction" (Squier, 1877, p. 113). Beside the adobe constructions, rammed earth buildings can be found in south America. In fact, during the XVIth century, the European settlers brought new building techniques. "In 1549 a Jesuit missionary sent a request to Europe to send 'artisans able to handle soil, and carpenters, for the construction of the Colégio da Companhia in São Paulo" (Jaquin, Augarde, 2012, p. 24). Monumental and vernacular buildings can be found also in other countries and, as it is stated by Houben and Guillaud, up to now, in Latin American countries, both earthen brick and rammed earth are still the main building materials (Houben, Guillaud, 1989).

## EARTHEN CONSTRUCTIONS BETWEEN PAST AND FUTURE

Earth is one of the most used materials in the construction industry: the conservation of the earthen heritage guarantees the safeguard of a technological culture that includes landscape and historical values. The transmission of knowledge connected to these constructions represents, together with the protection of material testimonies, the way through which foster the preservation of the earth culture and, therefore, the transmission of its civilization values.

The "culture of the earth", expression of the peasant roots of populations, is found in many settlements that are nowadays often strongly compromised. The progressive lack of their necessary maintenance, due to the widespread desire to replace raw earth with materials more "modern", "durable" and with "better" performances, has significantly contributed to their rapid degradation. They have often been abandoned or subjected to inappropriate interventions such as: demolition, substitution or reintegration adopting materials with characteristics different from those of the earth and responsible for the onset of degradation phenomena and their consequent rapid destruction (Haman, 2008, Mattone, 2010).

Recently, however, they have become the subject of renewed interest. The results of researches carried out during the last decades state the advantages of earth as a building material. Available in nature at an extremely low cost, earth requires a reduced energy cost for its processing and offers the opportunity to realise building with a remarkable living comfort thanks to its characteristics of breathability and thermal insulation (AA. VV. 2011; Fontaine, Anger, 2009).

Preserving and passing on knowledge about the material, construction standards and construction techniques can constitute important possible references for the creation of a new sustainable architecture. Therefore, the preservation of such material evidence should be promoted not only for the protection of the culture of the raw earth and for the transmission of the values of civilization that characterize it, but also

for a greater diffusion of sustainable architectures, with none or very low environmental impact.

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