

# Understanding and Managing the Constructive Characteristics of Vernacular Architecture

## *Two raw earth dwellings*

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**Abstract.** *In this paper a methodology will be presented to investigate and document the constructive characteristics of two raw earth houses: artifacts that belong to the vernacular architecture. The comprehension, analysis and documentation of these architectures presents several problems mainly linked to the impossibility of using a predefined method, because the difficulties relating to each artifact and its characteristics, to particular geographic, cultural and social situations, are unique. To understand and document the constructive features it was decided to realize a three-dimensional digital reconstruction of the two artifacts, using 3D modeling software. Subsequently several graphic works have been elaborated (technological breakdown, sheets with detailed information about the materials, used constructive techniques, etc), useful in managing a recovery or maintenance project.*

**Keywords.** *Vernacular architecture; raw earth dwelling; 3D modeling; digital reconstruction; knowledge management.*

## VALUES OF VERNACULAR ARCHITECTURE

In this paper a methodology will be presented to investigate and document the constructive characteristics of two raw earth houses, artifacts that belong to the vernacular architecture. The use of the adjective “vernacular” next to the word architecture was first used by Rudofsky (1987) and it means an artifact that has been built by common people (hence not by professional figures such as architects) to satisfy particular needs, such as to shelter or inhabit. This spontaneous architecture is widely diffused worldwide: it constitutes about the 90% of the world’s buildings (Oliver, 2003) and it possesses

a remarkable value because it is an expression of the environmental and cultural characteristics of a place and of the way of life of its population (May and Reid, 2010). It defines the identity of a site, its cultural diversity, hence it should be preserved for present and future generations. Furthermore, it represents a precious deposit of meanings, materials and constructive systems that can be used as a source of inspiration during the design and build of more sustainable buildings.

Unjustifiably the interest in the application of the digital technologies in this architectural sector

is not well diffused, although these constructions have inspired (and still inspire) many (even famous) architects (such as Renzo Piano for the Jean-Marie Tjibaou Cultural Centre in Noumea, New Caledonia, but there are other famous examples, such as Frank Lloyd Wright or Le Corbusier). They have particular spatial and material qualities, which make them more fascinating than many anonymous modern and contemporary buildings designed by professionals.

## ISSUES STUDYING VERNACULAR ARCHITECTURE

The artifacts belonging to vernacular architecture can be broadly classified into various categories: domestic, agricultural, industrial, religious, etc. Each of these categories can be further divided into subcategories: for instance, domestic architectures can be further divided according to the place (city, countryside, etc.) and to the dimension, but other differences can be taken into consideration (Brunskill, 1988). The technical-constructive solutions and the materials used in vernacular architectures strongly depend on the geographic features of the place where they are located: materials can be found on site and in surrounding areas, but climatic conditions, together with social and cultural aspects also play an important role. It is often possible to have very different constructive techniques within the same geographic area. The aesthetic, morphological and technical-constructive variety of vernacular houses worldwide is impressive (Oliver, 2003).

The comprehension, analysis and documentation of these architectures present several problems mainly linked to the impossibility of using a predefined method, because the difficulties related to each artifact and its characteristics, to particular geographic, cultural and social situations, are unique. This uniqueness characterizes the use of unique terms that indicate specific technical elements of a particular construction, and for this reason it is necessary to deepen the knowledge of the object that has to be studied through documents and the communication with local people.

## OBJECTIVE OF THE RESEARCH

The main objective of the research is to define and test a methodology to analyze and document the constructive characteristics of two raw earth houses. Raw earth is one of the most used building materials. The concept of constructive characteristics indicates the constructive system of an artifact, referring to the number and type of technical elements and the materials that comprise it, to which requirements it corresponds and how they are connected/assembled.

The analysis and documentation of the constructive characteristics of vernacular architecture is interesting for various aspects:

- to produce a knowledge (understanding of the artifacts) and documentation aimed to the definition of recovery, maintenance and renovation projects;
- to learn from the past sustainable constructive solutions that can be updated and used to create a healthier and more human built environment. These new solutions could be exported in other contexts having the same characteristics, and in this case this should be considered as “technological transfer”.

As time passed by, most of the know-how related to these constructions got lost, including the technical-constructive knowledge and the capacity of organizing a recovery site. It is not always possible to understand some technical-constructive solutions by only consulting the existing documents or observing the real artifacts. The digital technologies, and in particular the application of 3D digital modeling packages, allow us to investigate and compute many characteristics of buildings that have been built spontaneously, without a predefined design. Hence we can find out details such as the number and position of technical elements, the quantity of materials used and other technical/constructive characteristics.

## THE CASE STUDIES

For this research two dwellings located in two countries have been chosen (both belonging to

Figure 1

(Left) - Picture of the dwelling in Loreto, abandoned and in ruin (Source: picture provided by Prof. M.C. Forlani); (right) - Picture of the inner courtyard of the house in raw earth (Source: picture provided by the working group of Africa '70 project).



the Mediterranean area). In this way the similarities and the differences between the two constructive systems have been compared. The two artifacts belong to the same category, domestic building and have a similar size. Both case studies analyzed by the author belong to wider researches coordinated by Prof. M.C. Forlani (G.d'Annunzio University, Chieti-Pescara, Italy).

### General description

- **Loreto (Abruzzo, Italy):** The house (Figure 1 left) is located near Loreto, a small village in the countryside of the Abruzzo region, in central Italy. In this region there is a long tradition of raw earth buildings and to date a number of over 800 artifacts have been surveyed (Forlani, 2011). The typology of the artifact is a tower type, like many other buildings in raw earth in the region, and it is located in a rural area with no other buildings nearby. The constructive technique is the cob (made by clay, sand, straw, water and earth), but other dwellings in the region are also made by rammed earth.
- **Figui (Morocco):** The analyzed building (Figure 1 right) is located in the city of Figui in the eastern area of Morocco, at the border with Algeria. The city, built around an oasis, consists of seven ksour which are typical fortified villages in north Africa. In a ksar (that is a single

village) there are collective structures such as barns, shops, religious buildings and private homes. The houses have courts and they are all juxtaposed to form a compact urban tissue which facilitates defensive actions. The main constructive material for all the structures is adobe (the composition is similar to the cob, the difference is that the dough is shaped into bricks (using frames) and dried in the sun; in some cases it is possible also to find cut stone.

### Issues to be faced

- **Loreto (Abruzzo, Italy):** The artifact is abandoned and in ruin. Due to different climatic conditions (mainly snowfall and rainfall), the artifact is badly damaged, the roof and the floor are partially collapsed and also the perimetral walls present fissures. Moreover, the dwelling is surrounded by vegetation, in particular blackberry bushes. With this situation it was dangerous to enter inside the building or to move around easily and take more information and pictures.
- **Figui (Morocco):** In this second case the main difficulty was due to the impossibility of visiting the place personally, together with the necessity of analyzing a non-standard building system.

## METHODOLOGY

Both situations required the use of digital technologies of 3D modeling. To study and carry out the two digital reconstructions and create a series of graphic works to document the constructive peculiarities of the two raw earth houses, it has been defined a similar methodological process that can be synthesized in four main phases:

- Collection of documents;
- Analysis of the whole available documentation;
- Digital reconstruction (interpretation, modeling and organization of the elements);
- Representation and organization of the information in worksheets.

### *The digital reconstruction phase*

In order to understand and document the constructive features of an artifact, the most appropriate choice is the realization of a 3D digital model. The traditional two-dimensional drawings (plans, elevations and sections) do not allow an analysis, a representation and a proper communication of the constructive features. These graphic works are an ineffective theoretical description of the information concerning the technical elements and their relations in the three-dimensional space: this information can instead be provided by a 3D model. Moreover, the two-dimensional drawings have some inconsistencies which document and communicate the information in an unclear and wrong way, even because of difficulties caused by the irregularity of the technical elements that come from a non industrial production (hence not standardized). The two-dimensional drawings are not adequate for studying irregular morphological-constructive artifacts, because in these situations they appear to be excessively approximate.

The expression digital reconstruction means a process that foresees the action of building again as an existing artifact (or an artifact that no longer exists), in a virtual environment. This process possesses an autonomous value, independent from further analysis, because the same reconstruction process contributes to deepen and broaden the knowledge

of the artifact. During a process of digital reconstruction there are many choices to be taken.

During his Ph.D. research, the author examined and underlined the importance of some aspects that have to be considered when undertaking a three-dimensional digital reconstruction process, namely: abstraction, geometry and organization of the model. The model that results from the digital reconstruction is, like any other model, a simplified description of a system [1].

In the analysis of the artifacts and in the digital reconstruction as reference a classification scheme, namely the Italian UNI norms (UNI Norm 8289/2, 1981) has been used. In particular, these norms have been a useful support to the understanding and classification of a complex system made up of a hierarchical structure of the technical elements. The norms have been properly readjusted to describe a non standard building and only the classes of technological units available in the artifact have been selected.

### *The case study of Loreto*

The information gathered about the dwelling in Loreto are the results of some previous researches, including a photographic documentation, a two-dimensional survey in Autocad, that includes plans, elevations and sections, and worksheets with the information about technical elements (floors and walls) belonging to other raw earth dwellings of the region.

The dwelling, made of just two rooms is located on a slight slope and it is partially recessed in the ground. This characteristic affects the access to the two rooms positioned on opposite walls and at a different layout level. The room on the ground floor was used as stable/warehouse, while the room on the first floor represents the real dwelling and it was used as kitchen and bedroom.

Even in this case, like in the digital reconstruction of the Figuig dwelling, the two-dimensional drawings (properly cleaned of irrelevant information and reorganized into layers) have been really important within 3D Studio Max. The first elements

Figure 2  
(Left) - the constructive system of the floor (internal view of the room on the first floor);  
(right) - rendered view of the constructive system of the pitch roof.



to be modeled have been the four perimeter walls, built with the technique of the cob and tapered upward. The wall surfaces, because of the taper effect, are therefore inclined both inside and outside of the artifact. Three sides of the building are mutually orthogonal, while one side has a different inclination. The influence of this detail in the technical-constructive solutions clearly emerged during the study of the floor. The floor consists of a double frame of wooden beams: a main structure (beams of square section, 15 cm x 15 cm) and a secondary one perpendicular to the first (rafters of rectangular section, 8 cm x 3 cm). The beams are partially embedded in the masonry load-bearing and probably the rafters at both ends are embedded in the walls. The space between the beams is always constant, the only exception is the resulting surface between the last rafter parallel with the rest of the secondary and not the one built into the wall at right angles to the others. On the secondary structural grid is positioned a lattice of rods which constitutes the basis of a layer of clay (about 8 -10 cm thick) on which it is resting in the flooring tile brick (called "pianelle") of rectangular shape (Figure 2 left). The structure in raw earth did not allow large openings in the walls, which is why the number and size of windows are limited. On the first floor there are three windows, two on the ground floor. The openings have frames (lintels, jambs and sills) and fixtures (including the shut-

ters) in wood. The sills on the outside of the openings over the windows are in brick tiles ("pianelle"). The pitch roof has a bearing structure with a double wooden grid. On the second structural grid, similarly to the floor, is positioned a lattice of rods that constitute the base of a mantle in earth-straw. The external layer is made up by clay roof tiles (Figure 2 right).

In order to provide some quantitative data on the number of elements for this house two examples have been chosen: the tiles, about 310 for the pavement of the ground floor and about 366 for the flooring of the first floor (where have also been used on the input threshold of the house) and roof tiles, about 1007. Obviously, this numerical and quantitative information is indicative because there is the awareness of being in the presence of elements which do not result from manufacturing, and that can also significantly vary in size from one another. For both projects a set of textures to communicate the materiality of the technical elements has been created.

### ***The case study of Figuig***

The collected basic information include a photographic documentation, technical data on slabs and roofs, a two-dimensional survey in Autocad, which includes plans, elevations, and a section with the description of the materials. The artifact of study is



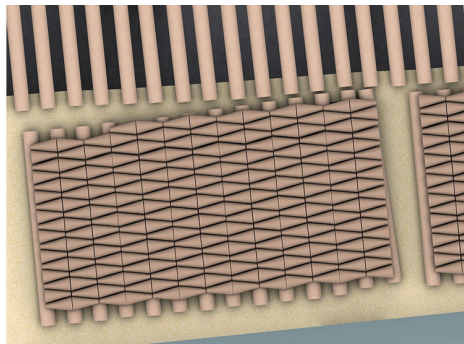
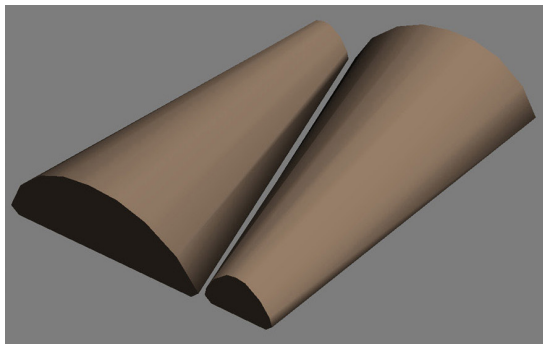


Figure 3  
(left)- rendered image of two *karnef*; (right) - closure of the slab in *karnef* on palm wood beams.

inserted within a compact urban settlement, characterized by buildings with courtyard. The walls border with other houses - therefore they are common walls - or with paths, some of which are covered. The building has a courtyard and three levels, two of which are practicable: the ground floor, the first floor and the roof/terrace.

The floor plans in Autocad have been cleaned by dimensions, crosshatchings and other non essential details, and imported in the 3D modeling software, 3D Studio Max. The use of a 3D modeler, instead of CAD software used for precision drawing like AutoCad, is the proper tool to model and manage a non standard artifact composed by a high number of objects on screen. Almost all the basic elements have been created through extrusions, and the most relevant exception is made of *karnef*, semi-triangular wooden elements that constitute the base of the palm trees.

This digital reconstruction investigated and documented the constructive aspects of the artifact, therefore for this reason special attention was paid to the analysis of the grid of the slabs. The grid is made of palm wood beams and the lower closure of the roof in contact with the beams is in *karnef*, which are elements that also play a structural function. The span between two beams where the *karnef* are placed is of about 34 cm; the *karnef* have an average size of 30 cm and they are between 3 and 5 cm high. The length of the palm wood beams varies between a minimum of 140 cm and a maximum of 270 cm.

This wide margin of difference comes both from the variable dimensions of the environments, and from the irregular thickness of the wall (Figure 3).

In order to cover all the spatial units in a constructively rational way and to understand the technical problems that could arise from this constructive technique, the beams and the *karnef* have been manually positioned, as if they were actually building the construction in a traditional way (Figure 4). Each beam has been rotated, spaced from the previous and adjusted in its length to correctly adapt itself to the spaces that have to be covered and to adjust the upper layer of the *karnef*. The position of the *karnef* on the same row is alternated and each row of *karnef* is mirrored with respect to the previous row.

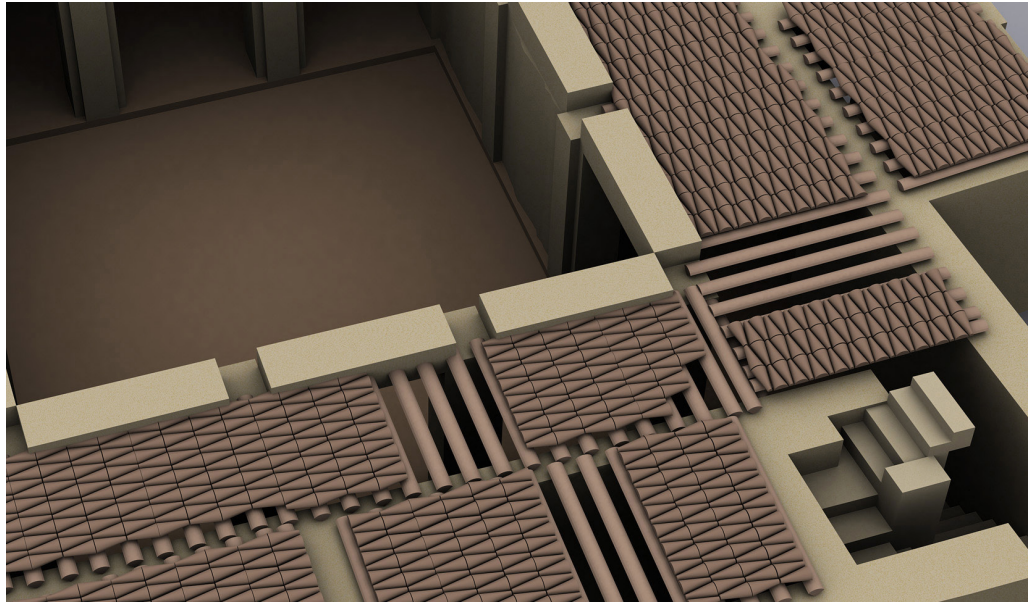
The digital model also allows to calculate/ assume the quantity of some technical elements necessary to build intermediate floors between the ground floor and the first floor (both floors of the court and those of the individual rooms): about 286 palm timbers on which are placed about 4209 *karnef* (1951 for the ceiling of the court and 2258 for indoors).

## REPRESENTATION AND ORGANIZATION OF THE INFORMATION IN WORKSHEETS

In both digital reconstructions all the technical elements have been grouped and divided per layer, according to categories of homogeneity, belonging to a floor plan or a specific field. The first prepared

Figure 4

*Rendered image of the grid and closure of the roof of first level.*

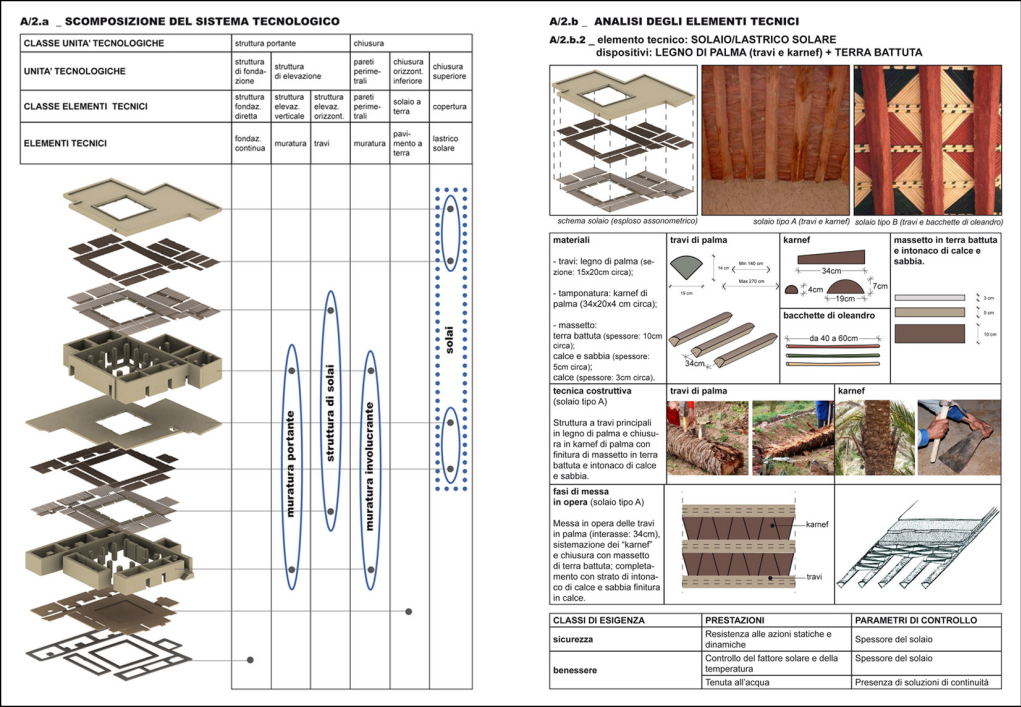


graphic work is the representation of the technological breakdown: an axonometric exploded view of different levels of the artifact, from the ground floor to the slab of the roof. The levels are related to re-adapted categories, from the UNI Norm 8290 of the technological breakdown. This scheme clearly communicates the affiliation of each layer to one or more of these categories, and therefore its function. Other graphic works are made of analysis worksheets of the main technical elements. For Figure 5 the masonry (Figure 5 left) and the slab (Figure 5 right) have been documented. The worksheets have detailed information about the materials, the constructive techniques, the constructive phases and the performances of materials and technical elements, referred to specific classes of requirements. The methods used to document the different construction phases, called evolutionary characteristics, have been described and analyzed by the author in other publications (Di Mascio, 2012a; 2012b). The obtained information has been reorganized taking into account the possibilities of realizing a database

to combine all the information gathered and elaborated during various inspections and researches.

## **DISCUSSIONS OF THE RESULTS AND FINAL REMARKS**

The realization of the digital models of the two dwellings in raw earth located in Morocco and Italy have allowed an in-depth study of their constructive systems and to hypothesize technical solutions adopted in some critical points which could be difficult to analyze and document in other ways. The produced information is useful to undertake technically efficient interventions on the built environment, without compromising the local architectural and constructive culture. As for other researches undertaken by the author in the field of digital media and cultural heritage (Di Mascio, 2009), the three-dimensional model was recreated in 3D Studio Max, because the digital reconstruction has required tools able to guarantee a better control of the frequent modifications and to quickly visualize various hypothesis on the adopted constructive solutions.





other fields of knowledge) it will be increasingly important to become aware of the importance of multidisciplinary approaches in order to bring the studies in this area to a higher level of detail and quality. Effective collaboration between specialists from different disciplines (architects, engineers, historians, anthropologists, archeologists, geographers, and many others) will largely depend on the ability of everyone to communicate to others in a clear and effective way information related to their area of expertise. Communicating the technical-constructive information only through two-dimensional drawings and texts could limit the comprehension and hence the capacity of other specialists to contribute to the research, influencing negatively the final result. The methods and analyzing instruments in the field of vernacular architecture are still too compartmentalized in the single disciplines and this could be limiting (Oliver, 2006).

## CONCLUSIONS

Within this research methods and tools to improve the comprehension and documentation of two raw earth houses have been investigated, elaborated and proposed. During the digital reconstruction phase it has been possible to interpret, suppose and document technical-constructive solution, that, in the best situations, could be understood only after several inspections, which could not be performed in both cases.

The reconstruction of a three-dimensional digital model can improve and expand the knowledge of vernacular architecture in order to improve the understanding, documentation, management, and conservation and simultaneously stimulate and evaluate the use of technical solutions and new constructions. Digital technologies and new theories and methodologies resulting from them are not intended to replace traditional methods and tools, but to complement and help to achieve new levels of accuracy and in-depth information and reflections. Textual descriptions and two-dimensional graphic works alone are not able to trigger some technical-constructive problems that come to light only dur-

ing the digital reconstruction. A continuous testing of additional case studies will be very useful to improve and expand the theoretical and methodological approach, and of course the use of various digital tools.

This approach can be used in an efficient way to rebuild and analyze many vernacular architectures in a digital environment; this refers in particular to huts, villages on stilts, buildings in stone, raw earth, and many other pertaining to different cultural and geographical environments worldwide.

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