Actas | Proceedings

6º Seminário de Arquitectura em Terra em Portugal (6º ATP)
9º Seminário Ibero-americano de Construção e Arquitectura com Terra (9º SIACOT)

Centro de Estudos Arqueológicos
das Universidades de Coimbra e Porto

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Digital Journal of Archaeology, Architecture and Arts

TRADITIONAL BUILDING TECHNIQUES OF THE DRÂA VALLEY (MOROCCO)

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ABSTRACT
The present work reports the results of investigations carried out on earthen constructions in the villages of Tamnougault, Tissergat, Amzrou and Tamngrout, in the Drâa valley (Morocco). This study aims to illustrate the techniques characterizing the local building culture, in order to understand its origins and motivation. Constructions show the use of both rammed earth (pisé) and adobe, used separately in different parts of the building. Floors and roofs are made with palm wood, canes and earth. The built heritage of the Drâa valley is an excellent example of high quality architecture, but also of how the local people and culture were able to respond in an excellent way to the environmental challenge, when the context was very poor in natural resources.

Keywords: local building techniques, pisè (rammed earth), adobe (mud brick).

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1. THE ARCHITECTURAL HERITAGE OF THE DRÂA VALLEY

The Drâa valley is located in the south east of Morocco, near the Sahara desert and houses one of the greatest treasures of earthen architecture in the World, consisting of *ksour* and *kasbahs*. The study presents the results of in situ surveys carried out by a team of the University of Florence, in successive missions (2006, 2007 and 2009) in collaboration with the Professional Building School of Florence and the Association de Développement de la Vallée du Drâa (ADEDRA). It concerns the elaboration of an inventory of local technical knowledge of construction characterizing the area.

The Drâa valley starts from the Saharan side of the High Atlas and then creates a wide valley at the base of the Anti Atlas, entering finally in the Sahara. The Atlas Mountains divide Morocco, not only geographically but also in lifestyles and in occurrences of architecture. Within the valley, consisting of a system of six oases with date palms, are, in fact, more than 300 *ksour*, or fortified berber villages, and *kasbahs*, fortified houses belonging to wealthy families and administrators of the territory and villages, constructed entirely with raw earth.

The heritage represented by these urban settlements is the proof of the existence of technical knowledge and skills accumulated over thousands of years of practice, local experience and handed-down know-how. These skills are being lost because figures like the foreman, and new young apprentices are disappearing. This has already happened in Europe in the past century. The Moroccan constructive "know-how", related to the traditional techniques, is likely to disappear because of the widespread use of reinforced concrete, considered as an index of development and progress, even if it brings results often completely inadequate for the environmental conditions.

2. CONSTRUCTION SYSTEM

2.1 The building process and the *maâlem* figure

In the Drâa valley, the building process depends entirely upon the maâlem, helped by two or three labourers. The *maâlem* is the foreman, the holder of the know-how; this person has the responsibility for the worksite, for unskilled workers, and for interacting with the client.

The work of the *maâlem* is artisan-like, there are no schools or training courses, it can be learned only empirically, with experience, handed down from generation to generation. The whole construction process is entrusted to the *maâlem*, covering the role of architect, director of project and the work.

The planning phase, as conceived in our cultural context, is inexistent. There is not a project design (often the *maâlem* can't write), there is just an idea that the *maâlem* and the customer construct together by talking, thinking, explaining and describing, which gradually forms the construction plan. All agreements are made orally and are based on trust. The construction sites and work tools are traditional and handcrafted.

The masonry techniques used in the Drâa Valley are rammed earth (*pisé* in French and *alleuh* in the local language) and adobe (*toub* in the local language) used separately in different parts of the building. Although these techniques are known and spread throughout the world, their implementation demonstrates local intelligence that permits the local people to adapt and protect themselves against the toughest aspects of the pre-saharan climate (heat and sand storms).

Generally rammed earth is used for the construction of the ground floor and first floor of the house (*dâr*), while adobe is used upstairs.

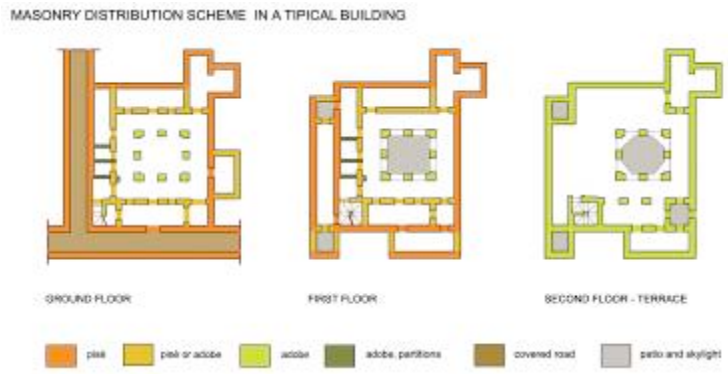

Fig. 1. Scheme example of the application of rammed earth and adobe masonry within a building. Case study of Hotel Dar Esseltane in Tissergat, Drâa Valley, Morocco. (credits: Baglioni E., 2009)

2.2 The building materials

In the traditional building of the Drâa Valley, a major role is played by the earth material, which is used for the walls, for the floors, for the roofs, for the mortar and for the plaster. The earth is used for its versatility in many different situations and it proves to be the most suitable material for an effective response to the warm-dry pre-desert climate. Besides earth, palm wood is used for horizontal structures, and canes are used for floors and roofs; finally we find a limited use of stones, mainly for the construction of foundations. All these materials are usually easily available on-site in good quantities.

The earth

The investigation revealed that the earth material is generally on site or in the close vicinity to the site. Thus, where the soil is not suitable, for example in the case of sandy soil, the earth is extracted from a common quarry.

In general, the most commonly used earth is the known as "*earth of the garden*" and it is found inside the palmery or in its surrounding areas. This earth due to its alluvial nature is rich in clay. The soil of the palmery is not everywhere the same. In spite of having a common base, it differs from place to place, even within small areas, and thus presents different characteristics.

Sometimes the earth of the palmery is mixed with the "*earth of the mountains*", a rocky terrain but friable, reusable at the bottom of the mountains. The soils are appropriately selected; the recognition is based on tacit knowledge, acquired over time and with experience. Custodians of this knowledge are not only *maâlmin* but the whole population.

The palm tree

The date palm is the backbone of the oases ecosystem of the pre-Saharan regions and marks the boundary between the Mediterranean culture and the Sahara. A palm tree is chosen to use as a building material, when it is no longer producing fruit. These trees are usually the highest and oldest, and as they are not easily pollinated, it is impossible to use them for date production.

The palm tree has not a high performance at a structural level because its trunk is not properly wood, but is made by parallel bundles of fibbers that, subjected to weight, do not ensure effective mutual cooperation and suffer intense inflections. However, the palm tree is the only wooden material available to use in construction. The problem is contained and controlled by keeping the lengths quite small, generally 2.00-2.50 m (up to a maximum of 4.00 m); dimension that becomes a proper module for the construction of any building.

3 THE CONSTRUCTION COMPONENTS

3.1 The foundation

More than foundations, we should speak of basements, with variable depths and heights, made with stones found on site, dry-walled or built with an earthen mortar. Depth, type, presence or absence of foundations depends of the soil type on which one has to build; of the type of wall or building; and of the role they

perform. Foundations are not always found. Sometimes the walls are erected directly on the ground. In the case of partitions or fences walls, it works with the casting of rammed earth or the laying of adobe directly inside of the excavation, to ensure interconnection within the wall and the ground. When present, thickness and height of foundations can vary even in the same wall. Their construction does not follow, apparently, a specific rule. We propose a classification based on 3 main types of foundations:

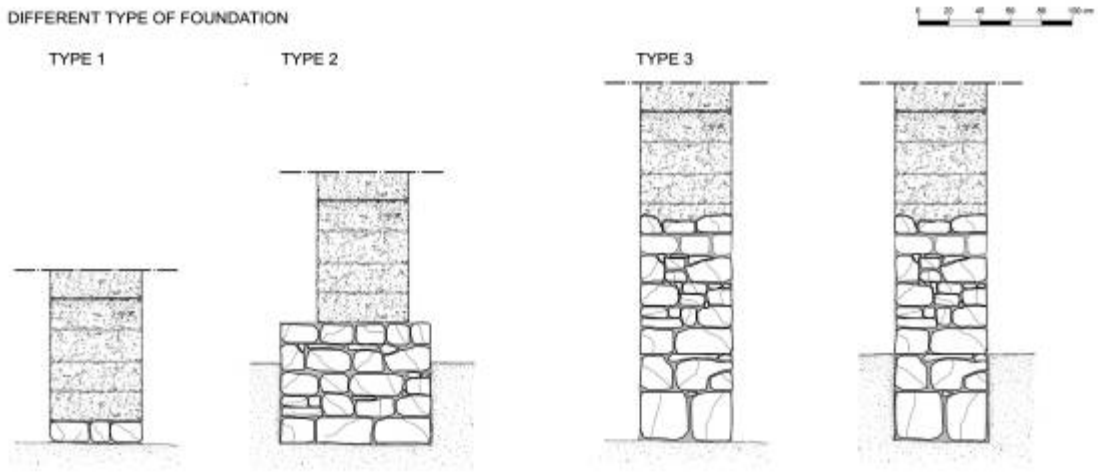

Fig. 2. Types of foundation. (credits: Baglioni E., 2009)

The first type consists of a thin layer of stones, 10-15 cm built at the base of the wall, directly on the soil and without excavation. In the case of rammed earth or adobe masonry, the stone for a dry wall foundation can be placed directly inside the formwork, before spreading the earth mixture. This type of foundation is generally built on solid ground and it is not subject to severe subsidence or on sandy and drained soils.

The second type of foundation is placed inside an excavation, to build up an interconnection with the ground. The excavation is made removing the surface layer to reach a more solid ground. Therefore, its depth is variable but estimated: around 50 cm below the level of soil. The width depends on the thickness of the wall and on the height of the building. This type of foundation is made wider than the wall, with a taper, more or less accentuated, that is often used to sit. However, the minimum width is 60 cm to allow the *maâlem* free movements in the excavation. The above ground heights of these basements are very variable. They start from a minimum of 20 cm, but may extend beyond a meter, especially in the corners or in doors reinforcement.

The third type of foundations consists of a stone basement of considerable height, with the same width of the wall. These foundations can be set directly on the soil or inside an excavation. The masonry wall, mainly rammed earth is sometimes set directly on the basement wall. To ensure greater continuity of construction, a layer of stones is made inside of the formwork before pouring the earth.

3.2 The rammed earth masonry

In the Drâa valley, the most generally used technique for the construction of load-bearing walls is rammed earth. It is also used for interior partitions of buildings or in the construction of houses or earth fence walls. The wall construction proceeds horizontally until the closing of the entire perimeter. An appropriate drying time (at least one week) is necessary to prevent deformation or collapse of the masonry.

This construction system, performed by shifting a single formwork or gauge box, from block to block, involves the adoption of a constant wall thickness along all the perimeter and generally, also on the whole height. The possible variation of the wall thickness is at the change of plan. For a 3-story building, 40-50 cm thick masonry is enough, while for higher buildings a 60-100 cm thickness is most relevant. The height of the floors is very variable, from 2.50 m to 5.00 m, but is proportional to the height of a

bond the exterior rammed earth with the interior adobe. Openings are usually made by breaks in the walls. The smaller openings (20-30 cm in width) do not require the use of a lintel.

After analysing the situation, it is evident that the bond between walls and partitions are not always successful. This produces walls that tend to detach and to act as a singular entity.

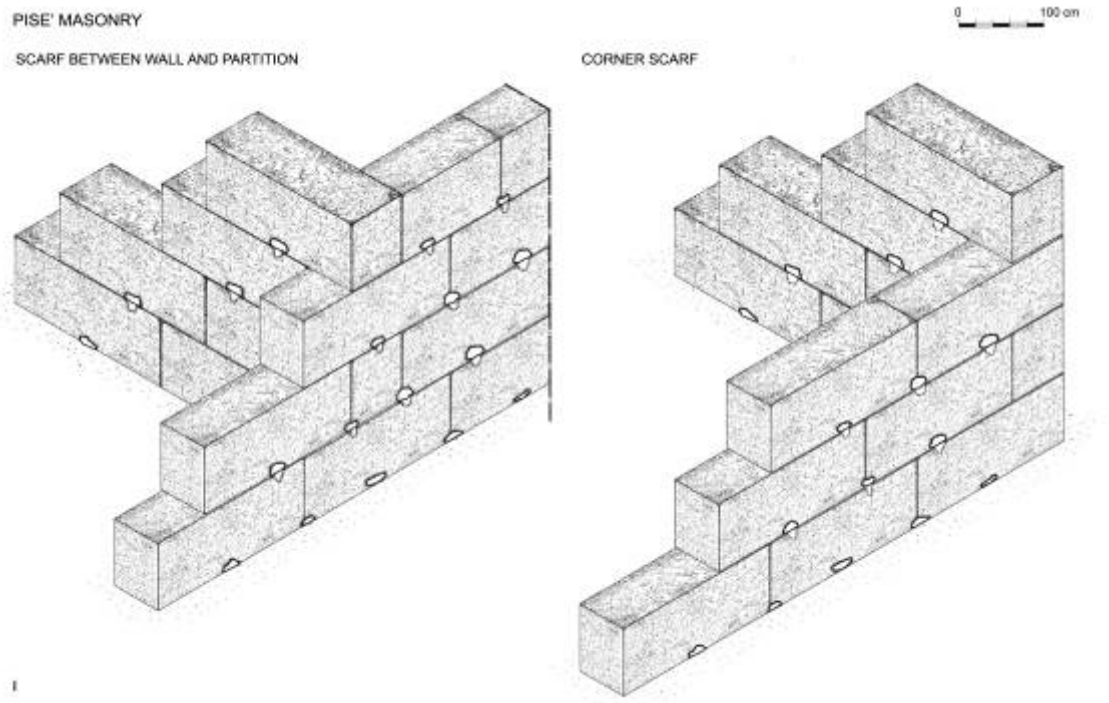

Fig. 3. Rammed earth (pisé). (credits: Baglioni E., 2009)

certain number of rammed earth blocks.

At each course level of the rammed earth, a scarf joint is created by over lapping the formwork between the lower and upper course to insure a good joint bond. The corner is created in the same way. The interior partition walls are generally built at the same time of the exterior walls. They retain the same thickness and are directly linked overlapping of the rammed earth. This requires constant planning of the building at various floors. When the partitions are made in adobe, a furrow is dug into the rammed exterior wall and a scarf joint is created to

Rammed earth, due to the construction system, has gaps in the wall consisting of holes left by the removal of the tie-rods of the formwork. These holes and the joints between the rammed earth courses are the weak points in the masonry and channels for water infiltration. Some of the wall cracking is mainly due to this reason.

3.3 The adobe masonry

In regards to the exterior walls, the adobe is generally used for upper floors, which are subject to minor loads, and where it is best suited for finishing and decor (adobe is also more expensive). In rammed earth, there are

portions that need to be made with adobe, due to the difficulty or even the impossibility of ramming the earth inside the formwork. The adobe is then used to complete the masonry above or to support the wood lintel or between floor beams, becoming here a string-course in the rammed earth masonry.

Whole monumental openings in prestigious buildings (*kasbah*) or in the fortified walls of the villages, are built with adobe so that arches and decorations can be built, using different dispositions in masonry.

Adobe plays its major role in patios, reaching the maximum of its bearing and decorative capacity. In the patio, the centre of the house and only interior space where there are decorations and architectural details, pillars and walls are entirely made of adobe. The adobes are also used to repair cracked masonry, both in adobe or in rammed earth, with the traditional "stitch-unstitch" technique. Even non load-bearing partitions in the house and the walls of the light shafts along the tunnel routes are made of adobe.

- The bricks are produced in different sizes but they are craft products, so, their size varies from site to site, from village to village. The walls are typically 40 cm, 50 cm or 60 cm thick and can be narrowed in the upper floors.
- The mortar consists of a mixture of earth and water, to which, rarely is straw added. When building with adobe, mortar is laid in horizontal joints between the courses, but rarely in the vertical joints. The joints are from 2 cm to 4 cm thick.
- The lack of order in the bonding pattern, lack of attention in the overlap or interlocking of the adobes and the presence of only horizontal mortar joints do not ensure proper bonding and offer little resistance in the masonry. When a load-bearing capacity is required, usually on the lower floors or patios, the work is clearly more regular and well-executed. For instance, with adobe laid flat with its longest dimension parallel to the side of the wall (stretcher) or laid up with its longest dimension parallel to the side of the wall.

3.4 The "patio" element

The patios can have different size and shape, characteristics that depend on construction techniques, climate and on the role that they have to play. From a spatial point of view, the patio is defined by a central space, bounded by two (or more) rows of arches or lintels on several spans, and by a perimeter tunnel, present on each floor, which creates a division between open and private rooms.

The architectural elements that define the patio are pillars, brackets, lintels and arches. They may be of different shapes and sizes and various combinations. The patio is always square shaped and, in relation to size, is composed with different number of span per side. In the *dâr* patios, there are generally 4 or 8 pillars, while in the *kasbah*, there are more patios of different sizes, but only in very rare cases do they have more than 4 spans per side.

3.5 The pillars

Pillars, *sserit*, play a key role in the architecture of the entrances of patios, villages and houses. Pillars are constructed in adobe and they serve as support for lintels and arches. In a structural role, the masonry is carefully executed, using adobe laid flat with its longest dimension parallel to the side and both horizontal and vertical mortar joints. Horizontal joints are generally very thick, up to 4 cm.

Pillars present various sizes with an average varying from 50 to 80 cm per side. In the *kasbah*, pillars present themselves with various forms: hexagonal, octagonal, circular or square with some rounded edges. However, the quadrangular form is the most common.

3.6 Lintels and brackets

The lintels are used for the opening of doors and windows in the adobe or rammed earth walls. Both lintels and brackets are made of palm wood, which, because of its fibrous nature, allows a limited length averaged from 2.00–2.50 m. being subjected to strong flexion. Given the significant thickness of walls, brackets and lintels are often made

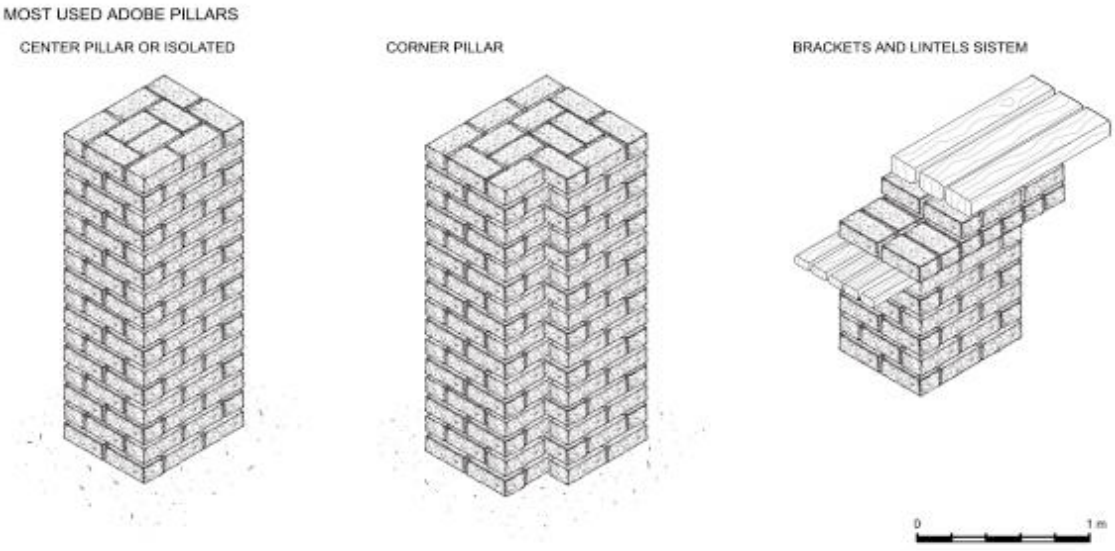

Fig. 4. Pillars, brackets and lintels. (credits: Baglioni E., 2009)

of several combined elements. They also present a variable width and a height that varies between 5 cm (for the brackets) and 10 cm (for the lintels).

3.7 The arch

The arches, *quis*, are part of the patio and of the entrance doors of the *ksar*, so it is evident that the arch is used in areas with symbolic and social significance. They are rarely used for doors and windows of houses, instead the rectangular shape is preferred. The arches are built in adobe and earth mortar and lean on pillars also in adobe, on the shutter there is (almost) always a wooden bracket. In patios, as well as monumental entrances, the arches are placed inside a portal structure. In the case of the patio, there is also a technical reason, because the slab is set on the wooden lintel.

In the case of the *ksar*, a fortified building in rammed earth, the side-support of the arch and a portion of the masonry above it, are always built with richly decorated adobe.

In the researched architecture (all from Berber ancestry), we find four different types of recurrent arches. They are a result of hybridisation and contamination with the Roman culture, and mainly, the Arab. The arches are:

- Round arches;
- Semicircular arches;
- Horseshoe arches;
- Ogive arches (far more frequent) with two different centres, moved from the axis of vertical symmetry; sometimes with lowered shutter (horseshoe) or raised above the centres.

Often, the arch is made with uncertain valuation, which results in irregular shapes, but in general, the "Arab" arches are always found in patios while the presence of the arch approaching to the full circle is detectable in the entrance of the ksar.

To construct the arch, first is prepared a wooden platform at the level of the shutter. The form can then be shaped by wooden elements such as an adobe lunette. The support must remain in place at least four days after the laying of the key. In the case of the ogive arch is missing the presence (and possibility) of a quoin key: hence there is always a discontinuity in the arch, settled with the laying of opposed bricks (in a design that has some overlapping V). There is a lack of a real key bow to generate a point of weakness in the arch.

The maximum light that can be achieved with arches in adobe is inevitably low (the largest generally do not exceed 3 meters). Sometimes there is the insertion of wooden

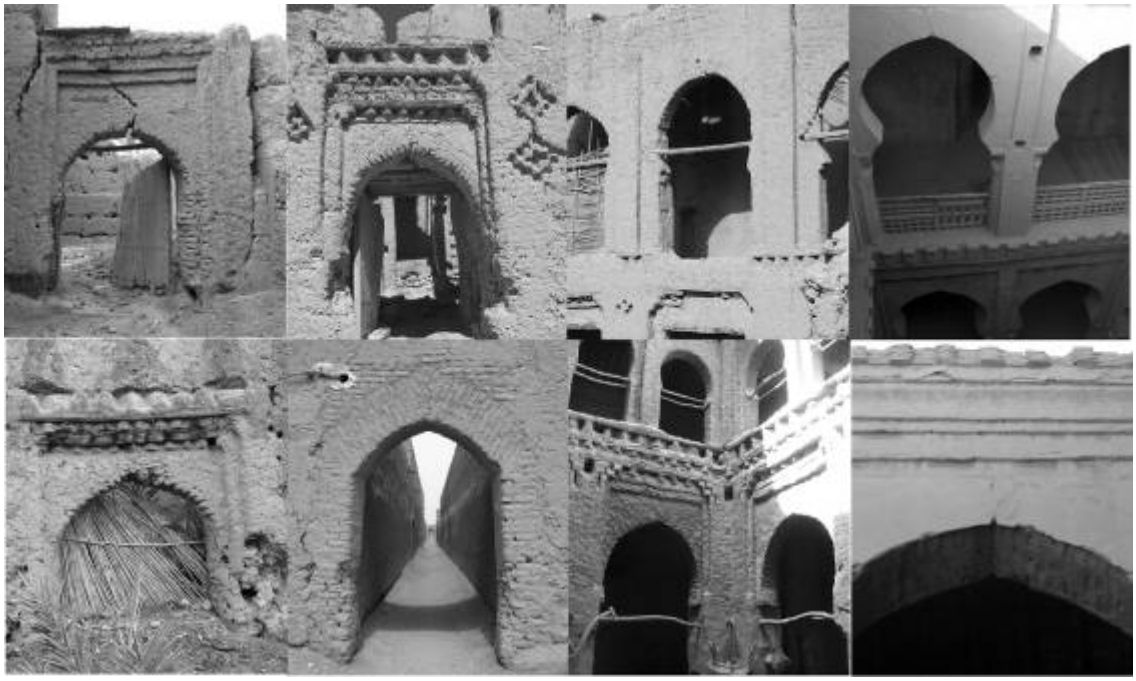

Fig. 5. Arches in the Drâa Valley (credits: Baglioni E., 2009; Cerkas, 2005; Mecca S., 2005; Rovero L., 2005)

chains, in order to control the pushing tension, but for the most part, the wooden elements present in the architecture of the patio are used to support curtains, furniture, etc.

3.8 The floors

The floors are made of a double wooden structure. The secondary beams are always warped perpendicular to the patio perimeter, and are based, on the one hand, on the centre line of the inner wall; on the other, on the wooden lintel of the patio that plays the role of main warping. Sometimes in the wall are inserted wooden planks at the support beams. Both in the wall and on the lintel, is placed at least a course of adobe as a plan for laying the beams of the floor.
The distance between the main beams depend on the presence or absence of further warping. In the absence of the joists (third warping), the beams are very close, with a inner axis between 30 cm and 50 cm, otherwise the beams are distant about 2 m one from the other, and the joists have an inner axis between 15 cm and 20 cm.

Beams and joists are made of palm wood in different sizes. More rarely are made of tamarisk. The tamarisk has better bearing performances than the palm, but it is less diffused and is more difficult to obtain straight beams. It is very recognisable when used, since the elements have circular cross section and an aspect of smooth wood, very different from the fibre and wrinkled palm. From the palm it is possible to obtain, on average, beams of a length of 2.0 to 2.5 m, 4.0 m maximum. This affects the size of the rooms, or rather the distance between the walls and/or the pillars.

The trunk is cut into slices of triangular cross section used in their raw state or, more rarely, shaped into rectangular sections. For the main beams, segments of the trunk are cut into 4 parts or rectangular sections of 30 cm x 20 cm. Secondary beams use segments equal to 1/6 of the trunk or sections of 20 cm x 10 cm. Joists use segments of 1/8 of the trunk or sections of 5 cm x 5 cm. Before being laid, beams and joists are left to dry in the sun to reduce moisture and thereby reducing the flexion under load. To verify the structural performance, the wooden elements are tested with the weight of a person after the installation.

As mentioned above, the beams rest on the centre line of the masonry, whether in

rammed earth or adobe walls. Above the secondary beams or joists, when present, layer of canes, called *tataoui*, are placed with decorative purposes. Above the *tataoui* was traditionally placed a layer of palm leaves, dried in the sun, in order to further limit the fall of dust. Today, the palm leaves are replaced by a plastic sheet that can be easily found in the local market. The thickness of the slab is completed with two layers of pressed clay soil, each about 5 cm thick. The first layer uses dry earth and the second uses earth in the wet state. Both are appropriately pressed with a special dish mallet called *dassassa*.

3.9 The roof

The roof of a traditional Moroccan home is flat. Roof terraces are very practical and useful, as they are part of the living space, especially in the summer months when they are used to sleep outdoors.

Above the wooden structure are the panels of *tataoui* made with canes and a layer of palm leaves or of the more recent plastic sheet. The next course consists of three layers of clay soil, each 5 cm thick, with different feature and made with different mixtures. The layers should be well compacted using the appropriate dish pestle called *dassassa*.

The first layer is made with an earth similar to that of rammed earth, slightly humid, but prepared with a finer earth. The second layer is dry and its function is to eventually absorb water infiltration when the layer above does not have a perfect seal. The last layer, in addition to serving as finishing must be impermeable to water, and therefore to consist of a moist mixture of earth and lime or earth and straw. Lime is a natural stabiliser which makes the clay impermeable and, once dry, stronger. If straw is chosen as additive, the mixture should be left to mature for 15 days and water is added daily and stirred.

The cover needs frequent maintenance because it is subject to degradation due to rain, wind and sandstorms. Maintenance is performed every 4 to 5 years, covering the existing layer with a new layer of earth and lime or earth and straw, and by doing so, a very thick layer of the last barrier can be reached gradually.

Bibliography

AA.VV., ADEDRA (2004). *Trésors et merveilles de la Vallée du Drâa*. Zagora (Maroc): Marsam. Work supported by UNESCO within the framework of "The Sahara of cultures and peoples".

AA.VV. (2005) Act of the *Forum UNESCO - University and Heritage, University of Florence Branch Office, 1st International Research Seminar on Architetctural Heritage and Sustainable Development of Small and Medium Cities in South Mediterranean Regions, Result and strategies of research and cooperation*. Florence (Italy): Ets.

- Biondi, B., *Morfologia degli elementi costruttivi a Tamnougault*, Marocco, 157-169.

- Lucci, G., Dania, S. *La kasbah del Caid di Tamnougault, analisi tipologica e costruttiva*, 133-144.

- Marrani, L., *La kasbah della famiglia Ait El Molehtar nello ksar di Tamnougault: rappresentazione grafica e analisi degli elementi architettonici e strutturali di una costruzione in terra*, 107-118.

- Módica, C., *Tecnica, processi costruttivi e terminologie della muratura in pisè in un'esperienza di cantiere a Tamnougault, Valle del Drâa, Marocco*, 171-178.

- Sánchez, N. R., *La kasbah «Igmi Mkaran» (del Pozo) en el ksar de Tamnougault (Marruecos)*, 119-131.

Ministère de la Culture, Maroc (CERKAS); Bureau d'Architecture et d'Urbanisme H. Hostettler, Berne; Institut de Photogrammétrie de l'EPF-Lausanne (2005). *Inventaire du pâtrimoine architectural de la Vallée du Drâa*. Retrieved March 15, 200915/03/09 from http://photpc15.epfl.ch/draa/html2/index.php.