TRADITIONAL BUILDING TECHNIQUES OF THE DRÂA VALLEY (MOROCCO)

Eliana Baglioni[1]; Saverio Mecca[2]; Luisa Rovero[3]; Ugo Tonietti[4]
Florence University, Italy.
[1]Mobile: +39 3496434744 E-mail: elianabaglioni@gmail.com
[2]Via San Niccolò 89/a, 50125 Firenze;
Mobile: +39 3473794966 E-mail: saverio.mecca@unifi.it
[3,4]Piazza Brunelleschi 6, Firenze, Italia.
Telephone: +39 0552757886 E-mail: luisa.rovero@unifi.it; u.tonietti@unifi.it

Theme 3: Techniques, Construction, Research and Development.
Keywords: local building techniques, pisè (rammed earth), adobe (mud brick).

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 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 not only of high architecture, but also of how the local people and culture were able to respond in excellent way to the environmental challenge in a context very poor in resources.

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 *ksur* and *kasbah*. The study we present here shows the results of in situ surveys carried on by a team of the University of Florence, in successive missions (2006, 2007, 2009) in collaboration with the Professional Building School of Florence and the Association de Développement de la Vallée du Drâa (ADEDRA), and concerning the elaboration of an inventory of local technical knowledge of construction characterizing the area.

Drâa comes from the Saharan side of the High Atlas and then create 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 the occurrences of architecture. Within the valley, consisting of a system of six oases featuring date-palms, are, in fact, more than 300 *ksur*, or fortified berber villages, and the *kasbah*, 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 and local experience and handed down with the know-how. These skills are being lost because figures like the foreman, and new young apprentices are disappearing. Like it has already happened in Europe in the past century, therefore in Morocco the constructive "know how" related to the traditional techniques is likely to disappear because of the widespread use of reinforced concrete, considered as 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 and for unskilled workers, and he responds to 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, handing it down from generation to generation. The whole construction process is entrusted to *maâlem*, covering the roles of architect, director of project and worker.

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

The masonry techniques used in the Drâa Valley are pisè, *alleuh*, and adobe, *toub*, 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 pisè is used for the realization of the lower stores, in the house (*dâr*) on the ground floor and first floor, while upstairs adobe is used.

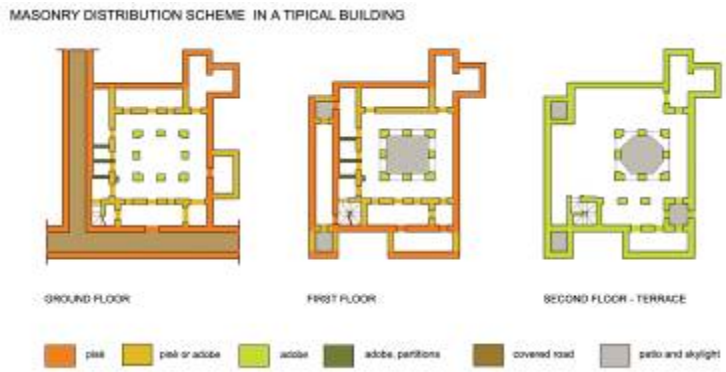

Fig. 1 – Scheme of the use of pisè and adobe masonry within a building. Case study of Hotel Dar Esseltane in Tissergat, Drâa Valley, Morocco. (credits: Baglioni E., 2009)

2.2 The building materials

In the traditional building technique in the Drâa Valley, the major role is played by the earth material used: for the walls, for the floors, for the roofs, for the mortar and for the plaster. The earth, used for its versatility in many different situations, proves to be the most suitable material for an effective response to warm-dry pre-desertic climate of the place. At the side of 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 realization of foundations. All these materials are easily available on-site and found in good quantities.

The earth

By the investigations carried out on site resulted with the following possibilities, the earth is taken on the site or in the close vicinity of the yard, on the contrary, where the soil is not suitable, for example in the case of sandy soil, the earth is extracted from a common quarry.

The earth most commonly used is the so-called "*earth of the garden*" that is found inside the palmery or in the surrounding areas, earth that, for its alluvial nature, is rich in clay. Lands of the palmery aren't, however, everywhere the same, they have common characters, but they differ from place to place, even within small areas, and thus present different characteristics.

Sometimes the earth of the palmery is mixed with the "*earth of the mountains*", rocky terrain but friable, resale at the bottom of the mountains. The lands 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. To use it as a building material, it is chosen from the palmery a no longer fruitful palm tree, usually one of the highest and oldest that, because it is not easily pollinated, it is impossible to use for date production.

The palm tree hasn't high performance at a structural level because its trunk is not properly wood, but is made by up parallel bundles of fibers that, subjected to weight, don't ensure effective mutual cooperation and suffer intense inflections. The palm tree is, however, the only wooden materials possible to used in construction field, so the problem is contained and controlled by keeping the lights quite small, generally 2-2.5 m (up to a maximum of 4 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 variables depth and height, made with stones found on site, dry-walled or with a earthen mortar. Depth, type, presence or absence of foundations are function 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 or, especially in the case of partitions or fences walls, it works with the casting of pisè or the laying of adobe directly inside of the excavation, to ensure collaboration within the wall and the ground. When present, thickness and height of foundations can vary even in the same wall, their realization doesn't follow, apparently, a very specific rule. We propose a classification based on 3 main types.

A 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 pisè masonry, stone foundation, if dry walled, can be placed directly inside the gauge box before the cast of the 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 instead is placed inside an excavation, to realize a collaboration with the ground. The excavation is made removing the surface layer to reach a more solid ground, its depth is, therefore, variable but estimated around 50 cm below the level of soil; the width, however, 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 as sitting; the minimum width is, however, 60 cm to allow the *maâlem* free movements in the excavation. The heights outside the ground of these basements, finally, are highly variable, starting from a

minimum of 20 cm, but may also extend beyond the meter, especially in the corners or doors reinforcement.

A third type of foundations consists of a stones basement of considerable height, with the same width of the wall; these foundations can be set directly on the soil or inside an excavation. On the basement is set directly the masonry, mainly in pisè; sometimes, to ensure greater continuity of construction, is made a layer of stones inside of the gauge box, before casting the earth.

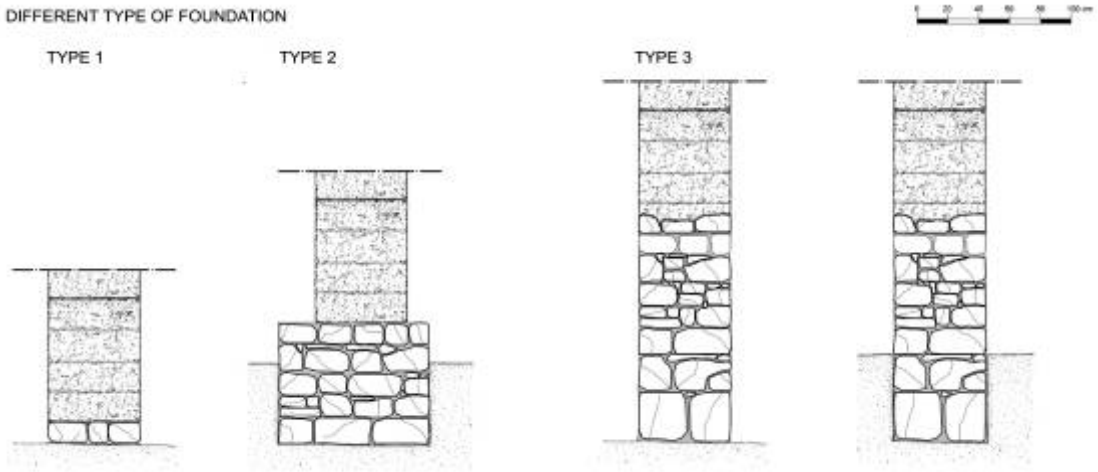

Fig. 2 - Types of foundation. (credits: Baglioni E., 2009)

3.2 The pisè masonry

The pisè technique is the most broadly used, in the Drâa valley, for the construction of load-bearing walls, but it is also used in interior partitions of buildings or in the construction of houses or land fence walls. The wall construction proceeds horizontally until the closing of the entire perimeter; after an appropriate drying time (at least one week), necessary to prevent deformation or collapse of the masonry, we proceed to realization of the higher level; the building is then raised for following "layers".

This construction system, performed by shifting a single gauge box, from block to block, involves the adoption of a constant thickness of the wall along all the perimeter, and generally also on the whole height; possible variation of the thickness of the wall is at the change of plan. For a 3-storey building, 40-50 cm of thickness masonry is enough, while for more highest buildings are needed most relevant thicknesses, from 60-100 cm. The height of the floors is very variable, from 2.5 m to 5 m, but is proportional to the height of a certain number of pisè blocks.

To ensure the masonry scarf, at each "ring" of pisè is made a mismatch of the gauge box from the below level, the corner is treated in the same way. The interior partition walls are generally built at the same time of the perimeter walls, they retain the same thickness and are directly linked through the mismatch of the pisè block; this requires constant plan of the building at various floors. When the partitions are made of adobe, the scarf with the perimeter walls is realized by digging a furrow in the pisè. As for openings, they are usually made by interruption of the masonry, for the smaller, 20-30 cm in width, it isn’t necessary to use a lintel.

Analyzing the situation is evident that the scarf in the cantonal and between walls and partitions are not always successfully, thereby producing non-cooperation and non-linked walls that tend to detach and act as single sheet walled.

The pisè, for its mode of implementation has discontinuity points of the masonry, consisting of the holes left by the inferior transverse of the gauge box, once unthread. The holes and joints between the pisè blocks are weak point in the masonry and favorite channels for the water infiltration; for this reason cracks in the walls corresponds mainly to them.

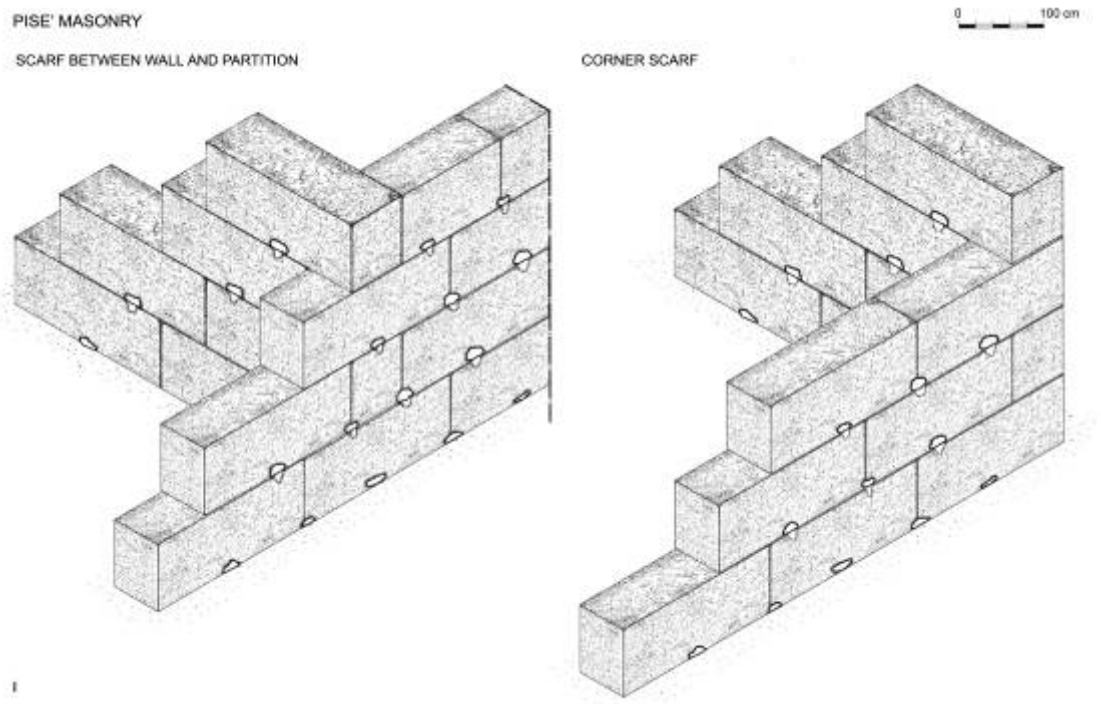

Fig. 3 - Pisè masonry. (credits: Baglioni E., 2009)

3.3 The adobe masonry

Regarding the perimeter walls, the adobe is generally used for upper floors, which are subject to minor weight, and where it best suites for finishing and decor (it's also true that the work in adobe is more focused but also expensive). In a pisè masonry there are portions that need to be made with adobe, for the difficulty or even the impossibility of pressing the earth inside the pisè gauge box. 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 pisè 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 realized, 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, pillar and walls are entirely made of adobe. The adobe, finally, are also used to repair cracked masonry, both in adobe or in pisè, with the “stitch-unstitch” technique. Even partitions, not load-bearing, internal to houses or bounding 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 have typically thicknesses of 40 cm, 50 cm or 60 cm and can shrink at the upper floors; it is masonry of 2, 3 or 4 heads based on the size of bricks.

- Masonry dispositions are very variable, the bricks are laid on the long side, head-like, knife-like, obliques and herringbone. Analyzing the condition of things is evident that only in rare cases it has regular and constant course within the same masonry.

- The mortar consists of a mixture of earth and water, to which more rarely straw is added. In the realization of adobe, the mortar is laid in horizontal joints between the courses, but rarely in those verticals. The joints are thick, from 2 cm to 4 cm.

- The lacking order in the course disposition, the little attention in the offset of adobe, the presence of mortar only in horizontal joints, do not ensure proper cooperation between the elements and produce, therefore, lack of linkage and little resistance masonry. Where a load-bearing capacity is required, usually on the lower floors or patios, the equipment is clearly more regular and well-executed, with adobe laid on the long side, and head-like or on the long side and knife-like.

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 the 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 perimetral tunnel, present on each floor, which creates a plan of exchange between vacuum and private rooms.

The architectural elements that define the patio are pillars, brackets, lintels and arches, which may have different shapes and sizes and be variously combined. The patio is always square shaped and, in relation to size, is composed with different number of span for 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 they show more than 4 spans for side.

3.5 The pillars

The pillars, *sserit*, play a key role in the architecture of the patios and of the villages and housing entrances, serving as support for lintels or arches, but are frequently used leaning against walls to reduce beams length or in the internal room partition. The pillars are made in adobe, with masonry of 3, 4, 5 or 6 heads based on the size. Play a structural role, the masonry is carefully executed, using adobe laid on the long side, and on the head and mortar both in horizontal and vertical joints; horizontal joints are generally very high, up to 4 cm.

The pillars are made in various forms, typically starting from a quadrangular form, and in various sizes, on average between 50 cm and 80 cm for side. The most common form is the rectangular (or square) are sometimes also used jagged pillars or cross-shaped. In the *kasbah* can also be found more articulate pillars, hexagonal, octagonal, circular or square with some rounded edges.

3.6 Lintels and brackets

The lintels are used not only for the opening of doors or windows in the adobe or pisè masonry, but also in the central patio, as a link between the pillars in the case of portal openings. The brackets are used in conjunction with the pillars, as a plan of shutter for lintels or arches; in some cases, between pillars and lintels, there is a double row of bracket that create a kind of capital.

Both lintels and brackets are made by palm wood, which, for it’s fibrous nature, allowing limited light (on average 2–2.5 m) and it is subject to strong flexion. Given the significant thickness of walls, brackets and lintels are often made of several elements

combined, of variable width and height between 5 cm (for the brackets) and the 10 cm (for the lintels).

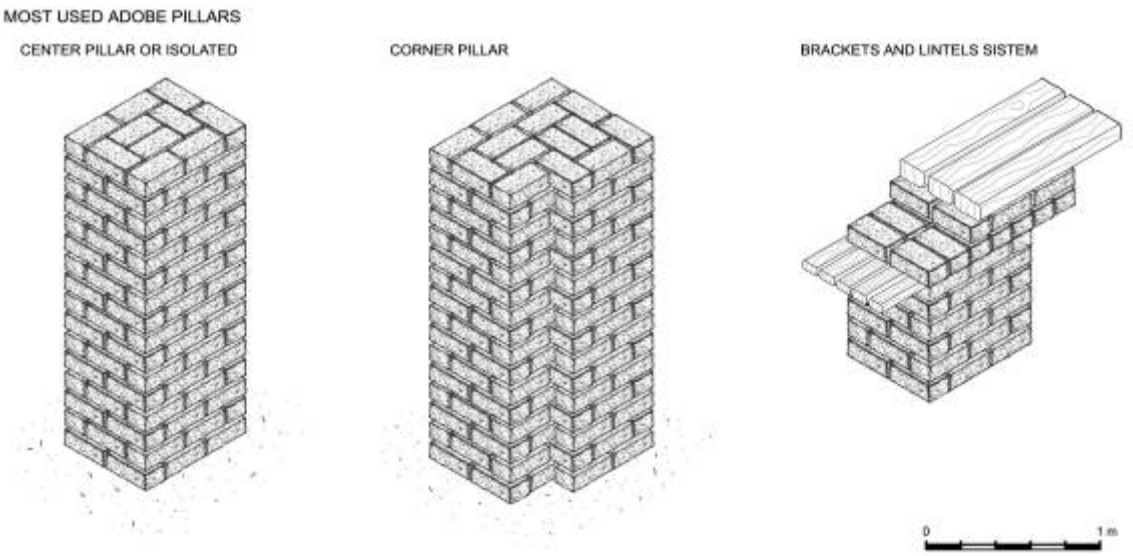

Fig. 4 - Pillars, brackets and lintels. (credits: Baglioni E., 2009)

3.7 The arch

The arches, *quis*, are part of the patio and of the entrance doors of the *ksur*, so it is evident as the arch is used in areas with symbolic and social significance. They are rarely used for doors and windows of houses, where, instead the rectangular shape is preferred. The arches are built on adobe and earth mortar and lean on pillars also in adobe, on the shutter there is (almost) always a wooden bracket. In the patio, as well as in the monumental entrance, 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 *ksur* doors, that can be defined as small buildings with its own characteristics and where we also find pisè walls, the side-support of the arch and a portion of the masonry above it, which, as the patio, is richly decorated, is always realized with adobe.

In the investigated architectures (all from Berber ancestry), we find four different types of recurrent arches, result of hybridization and contamination with the Roman culture, or mainly, the Arab one: round arches, either semi-circular, either in a horseshoe (with lowered shutter) or (far more frequent) ogive arches (with two different centers, moved from the axis of vertical symmetry) sometimes with lowered shutter (horseshoe) or raised above the centers. 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 ksur.

To realize the arch is first prepared a wooden platform at the level of the shutter. The form can then be shaped either by wooden elements as by an adobe lunette; the support must be removed no earlier than four days from the laying of the key bow. 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). The 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 not exceed 3 meters).

Sometimes you look the insertion of wooden chains in order to control the pushing tension, but for the most part, the wooden elements present in the architecture of the patio are useful for supporting curtains, furniture, etc...

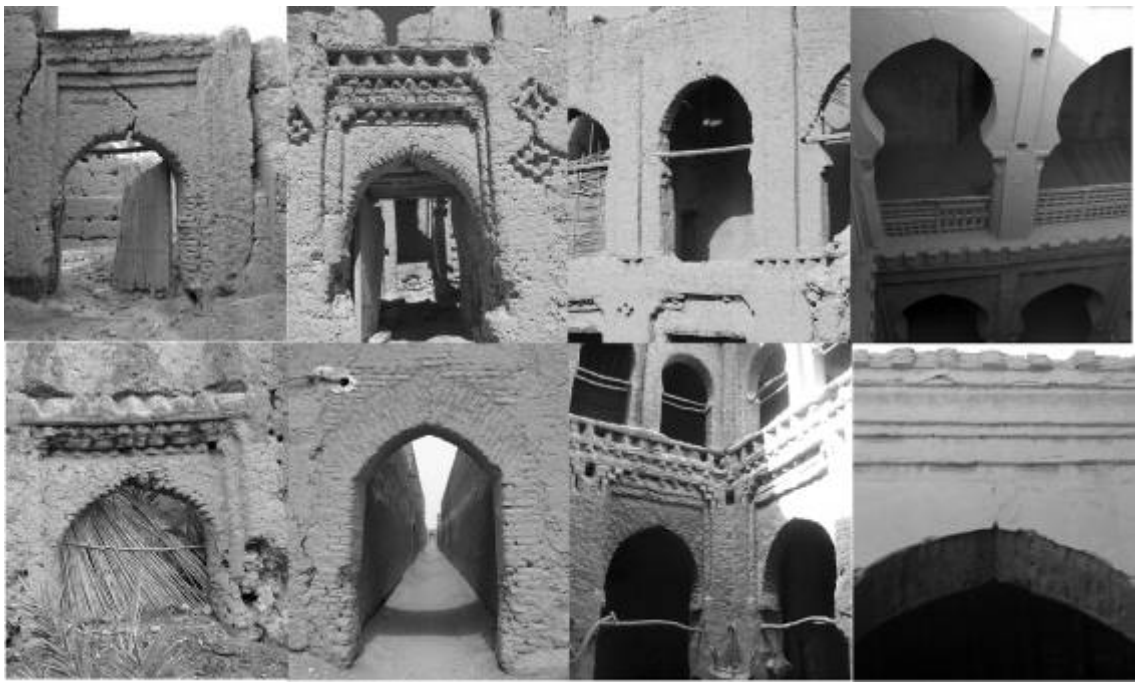

Fig. 5 – Arches in the Drâa Valley.
(credits: Baglioni E., 2009; Cerkas, 2005; Mecca S., 2005; Rovero L., 2005)

3.8 The floors

The floors are made of a wooden structure at least double. 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 of the palm, but is less diffused and is, however, more difficult to obtain straight beams; when is used is very recognizable since the elements have circular cross section and an aspect of smooth wood, very different from the fiber and wrinkled palm. From the palm is possible to obtain, on average, beams of a length of 2-2.5 m, 4 m maximum; distance that necessarily 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 are used segments of the trunk cutting into 4 parts or rectangular sections of 30 cm x 20 cm, for secondary beams are used segments equal to 1/6 of the trunk or sections of 20 cm x 10 cm; for the joists, finally, slices of 1/8 of the trunk or sections of 5 cm x 5 cm. Before being laid, beams and joists are left to dry at the sun to lose moisture to the wood and thereby

reducing the flexion under load; to verify the structural performance, the wooden elements are tested to the weight of a person after the installation.

As above mentioned, the beams rest on the centre line of the masonry, whether in pisè or adobe. On the remaining half of the masonry and in the free space between one beam and the other, on the whole thickness an adobe masonry is made. In the first instance to the extrados of secondary beams or, if are, of the joists. This adobe brick, if resting on masonry pisè, constitues a sort of recognizable string-course in the absence of plaster.

Above the secondary beams or joists, when present, is placed a layer of canes, called *tataoui*, which has decorative purposes, distribution of loads on the wooden structure and limit the fall of dust. Above *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 on the local market. The package of the slab is completed with two layers of pressed clay soil, both the thickness of about 5 cm. For the first layer using the dry earth, for the second earth in the wet state, both are appropriately pressed with a special dish mallet called *dassassa*.

3.9 The roof

The roof in traditional moroccan homes, but also in many other areas of the Mediterranean and not, have flat roofs because there aren't major need to depart, whit groundwater, the already scarce rainwater. The roof terraces are very experienced and used spaces, an integral part of living spaces, especially in the summer months when they are used for sleeping outdoors.

From a technological point of view, the floor covering, having to perform the function of protecting the entire building from the climatical agents, differs from the floor in the amount and quality of the earthen layers and, therefore, in thickness.

Above the wooden structure are yet the panels of *tataoui* made with canes and a layer of palm leaves or of the more recent plastic sheet.

The next package consists of three layers of clay soil, thickness of 5 cm each, with different feature and made with different batters. The layers should be well compacted using the appropriate dish pestle called *dassassa*.

The first layer is made with an earth similar that of pisè, so 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 did not have a perfect seal. The last layer, in addition to serving as finishing must be impermeable from water, is therefore performed with a moist mixture of earth and lime or earth and straw. Lime is a natural stabilizer which makes the clay impermeable and, once dry, the dough stronger. If the straw is chosen as additive, the mixture should be left to mature for 15 days daily by adding water and stirring.

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

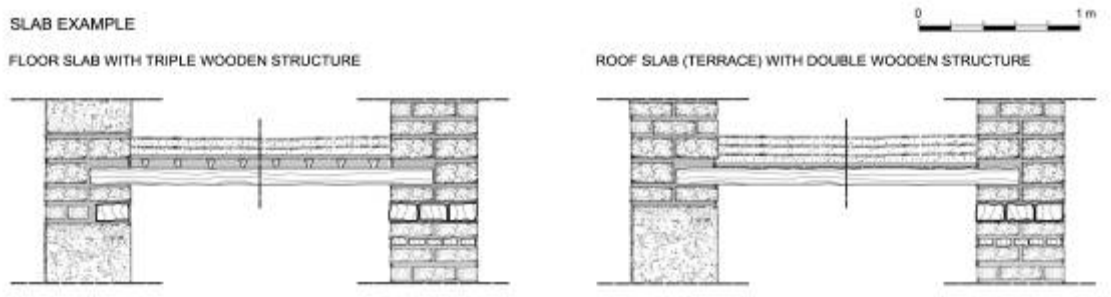

Fig. 6 - Slab and roof. (credits: Baglioni E., 2009)

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, pp. 157-169.
- Lucci G. e Dania S., La kasbah del Caid di Tamnougault, analisi tipologica e costruttiva, pp. 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, pp. 107-118.
- Modica C., Tecnica, processi costruttivi e terminologie della muratura in pisè in un'esperienza di cantiere a Tamnougault, Valle del Drâa, Marocco, pp. 171-178.
- Sánchez N. R., La kasbah «Igmi Mkaran» (del Pozo) en el ksar de Tamnougault (Marruecos), pp. 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.*
Available at: http://photpc15.epfl.ch/draa/html2/index.php (Access: 15/3/09)

Curriculum

Eliana Baglioni, architecture graduation at the University of Florence, Italy. She participated in many initiatives related to earthen buildings and in general to bioarchitecture. Participation as coauthor of a paper at the Congress *Ripam 2*, Morocco (2008).

Saverio Mecca, full Professor of Building Production at the Department of Architectural Technologies & Desing – TAED, of Florence University, Italy. Since 2007 he is Director of the INN-LINK-S Research Center, oriented to investigate local and traditional knowledge systems in the field of architecture, agronomy and material cultures with an interdisciplinary scientific approach.

Luisa Rovero, architect and PhDoctor in "History and Science of building techniques". She is Assistant Professor of "Structural Mechanics" at the University of Florence. Her research activity is mainly focused on mechanical behaviour of masonry and earthen structures and consolidation techniques for historical buildings.

Ugo Tonietti, architect, is Associate professor of "structural Mechanics" at the University of Florence; his current research activity is mainly focused on consolidation techniques for

historical buildings. As architect he as studies and designed structural rehabilitation for historical heritage.