Sustainable Vernacular Architecture: The Case of the Drâa Valley Ksur (Morocco)

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Abstract

The Drâa Valley is located in the south east of Morocco, near the Sahara desert and houses one of the greatest earthen architecture heritage in the World, consisting of ksur and kasbah. The built heritage of the Drâa Valley is an excellent example of how the local population and culture have succeed to respond in a sustainable way at the environmental challenge, starting from the environment characteristics and the construction materials availability.

The materials used are available on site and are totally natural, so they are environmentally friendly, renewable, reusable and have very low production and processing costs.

The ksur of the Drâa Valley are just one of countless examples of sustainable architecture in the traditional architectural heritage worldwide, but we have wanted to take as an example to reflect on vernacular architecture, considered in their complexity as a type of settlements, housing and construction techniques.

In the sustainability building and housing response points of view, it seems interesting and necessary to reassess the traditional architectures, improve theme, where necessary, and adapting to the current life and cultural context. The same consideration should be done on earth, too often considered a poor and unworthy material, which instead offers many advantages as a building material. The different soil have a great adaptability for construction use, are easily available and have high thermal and acoustic performance, the earth mixture are easy to prepare, building techniques and the implementation doesn't require specific technologies, so as to enable the self-construction.

Keywords: *traditional building techniques, row earth, sustainability*

1 .Reflections on The Current Situation

The human being, as dominant species of the planet, has over the centuries "forgot" to belong and depend on a complex environmental ecosystems that, in fact, allow him to live, going to affect the natural equilibrium in a always less reversible way.

The last centuries of human history have been characterized by uncontrolled industrial expansion that has defended and developed technologies that require a high energy and water consuming, with an almost total dependence on fossil fuels that continue to be treated as inexhaustible sources knowing that it isn't. Human carelessness and the absence of self-control in the resource management have compromised and transformed the natural ecosystems: issues such as climate change, ozone hole, biodiversity loss, environmental pollution, desertification, deforestation, increasing of natural disasters, genetic alterations, water and air pollution, are some of the direct consequences of our development.

Figure 1: Reinforced concrete building in a Marrakech expansion area, Morocco. (Credit by Baglioni E., 2009)

over 70% of the global energy used, is for the construction trade, including production of materials, transport, construction and operation of buildings. The construction, therefore, creates a big impact on the environment consuming a large amounts of non renewable natural resources, and also produces, either directly or indirectly, a large amount of residues and pollution. Actually, most of the building construction is related to the industrial sector that is strongly integrated in the society, eroding consolidated life styles based on the idea of building the house according to own taste and own traditional languages, and to live in relation with the open space. The reinforced concrete building has gradually established itself as a universal model, even where the climatic and environmental conditions make it totally unsuitable, and it has destroyed the agricultural lifestyle and a mental and psychological balance.

The technology and the development should be flexible means, capable of producing different living conditions, related to certain places and societies, and to the requests of a certain time, but on the contrary, the imposition of universal models and lifestyles has reduced ductility and elasticity of the technological means. Consequently, have spread prejudices related to "rural" and natural materials, which have given rise their use as "poor", convinced by the idea that industrialization represents progress and is recoverable in any part of the World, forgetting the differences of climate, culture and local traditions. Industrial civilization has had a strong influence on the mind attitude, managing to persuade the traditional world of being in need, in the backwardness and in the inferiority (Dalla Casa, 2009).

2 Traditional Techniques And Traditional Construction Types Sustainability

At the points of view of the building sustainability and the housing response, the re-discovery and revaluation of traditional building techniques are interesting and necessary, because these techniques are sustainable by their nature.

The birth of traditional building techniques was mainly caused by climatic and natural factors or else by environmental characteristics and availability of building materials. The construction technique is the means through which a particular culture is able to implement its response to environmental challenge, not by chance wood and earth are the two natural building materials most used in the elementary building process, because the most widespread and available throughout all Earth's surface.

The housing form is rather influenced by human and cultural factors: the social structures, the lifestyle or the relationship between the house and the principal economic activity, may to affect the shape. The traditional houses types, in their complexity, are one of the highest expressions of human know how, because that come from by a slow experimentation process, born spontaneously and perfected, step by step, in the slow course of time with the experience and the observation, going to eliminate or refine each inappropriate or unsatisfactory solution. The traditional houses types are the specific response to the housing demand dependent on the various local factors (Cataldi, 1988, pp. 23-51). Traditionally, the materials used for the construction are those available on site, today called a "zero distance", that comport, therefore, lower transportation, production and processing costs, in most cases it is moreover natural materials, then green, renewable and reusable. In summary, the traditional houses type, is the result of the symbiosis between a determined culture and a specific geographical training area, which generates, however, a number of possible variants; often traditional types are those that best fit into the context landscape.

2.1 2.1 The Drâa Valley ksur (Morocco)

In support of the above, I propose the example of the sustainability of the Drâa Valley ksur, which I had the opportunity to meet directly.

The Drâa Valley is located in south east of Morocco near the Sahara Desert, and host one of the greatest raw earth architectural heritage of the World. The Valley, which is the middle course of the river Drâa, separates the Eastern Anti Atlas by the Western Anti Atlas and consists of a 6 oasis system, characterized by palm forest.

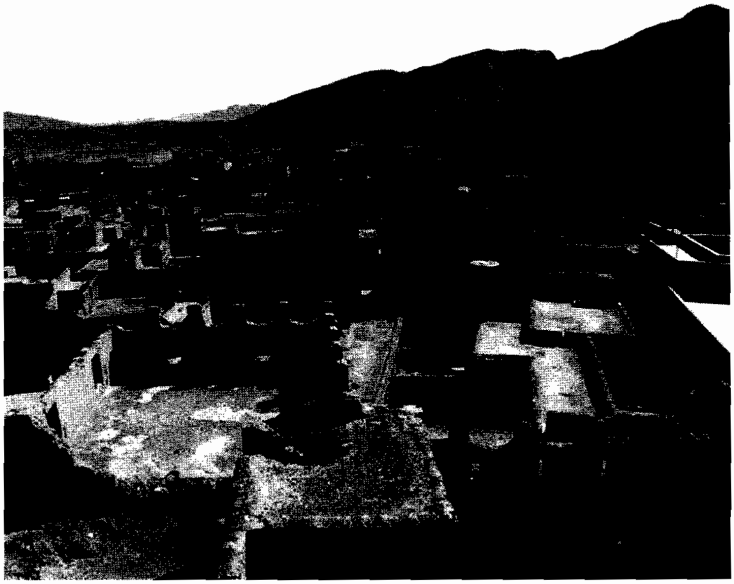

Figure 2: Ait Hammou Ou Said ksar, in the Drâa Valley, Morocco. (Credit by CERKAS, 2005)

The Atlas Mountains divide Morocco not only geographically but also in lifestyles and in architecture occur, along the Drâa Valley, in fact, among the palms, there are over 300 ksur, berber villages constructed entirely with raw earth. These village, rural and fortified, are characteristic of the Drâa and Dades Valleys and date from the fifteenth century, period when the sedentary Berber population was the need to close the villages with high walls and defensive towers, caused by the continuous attacks of the nomadic Berber tribes. The ksur (sing. ksar) have a very dense urban fabric, with houses built each against other in order to defend each other from the warmth, in addition, often the first floor is constructed on bridge on the road, thus creating, below, a fresh and dark tunnels grid, that protect from heat and sand storms (Baglioni, 2009, pp. 22-34). It is interesting to see how this type of aggregation simulate the underground architectures, enjoying the advantage of thermal insulation and, at the same time, solving the big problem of ventilation (Bourgeois, 1988, p. 48).

In addition to ksur, the Valley is spread with kasbah, big fortified houses belonging to berber families who protected the villages and adjacent territories, or, later, belonging to the representatives of Pasha Glaoui, who exercised administrative control until the Morocco independence.

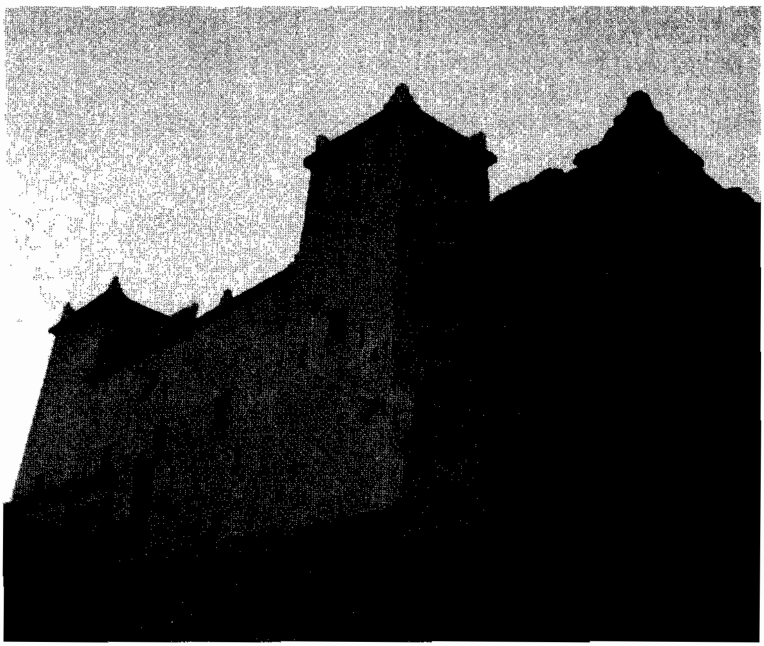

Figure 3: Kasbah Dâr El Hiba into the Tissergat ksar, Drâa Valley, Morocco. (Credit by Baglioni E., 2009)

Both in the kasbah and into the ksur, the housing type used is constant and recognizable, is a patio house. This type, with its specific and different models, has spread not only throughout Morocco, but throughout the Arab World and the Mediterranean. The patio is typical of the Arab-Muslim housing and is identified with the centre and the heart of home and family life; it's a place to live, active, but at the same time intimate and collected. In the Drâa Valley building, the patio isn't just a vertical hole in the building, but it's defined by a perimeter gallery present at all floors, which creates a trading plan between the central vacuum and the private rooms; the patio size and shape are determined partly by local building techniques and climate and partly by the local traditional culture.

The importance of this space in the housing composition is also expressed in the architectural details and decorations, that are very rich compared to other walls where there aren't specific details (Baglioni, 2009, pp. 38-43 & 51-55).

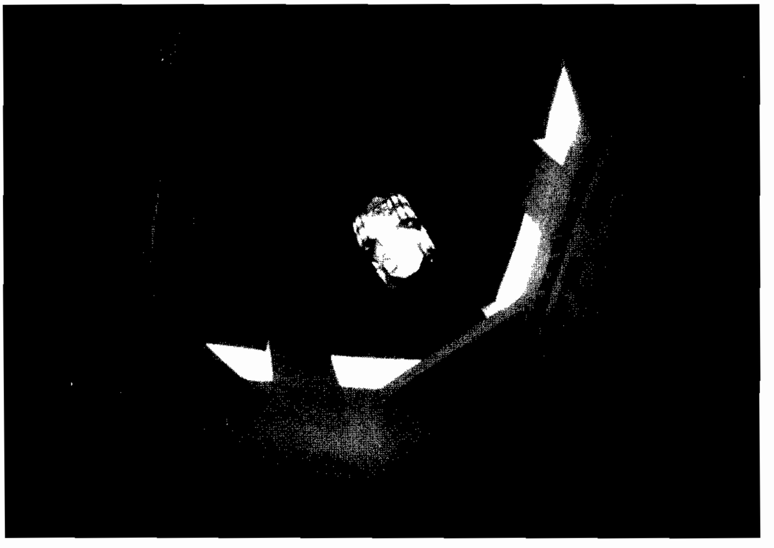

Figure 4: Internal view of a patio in Tissergat ksar. (Credit by Baglioni E., 2006)

The typical plant of the house, called dâr, presents three wall square inscribed one inside the other. The largest is the perimeter of the house, the smallest coincides with the central patio characterized by arches that rest on 2, 3 or 4 pillars on each side. The intermediate square corresponds to the wall separating the rooms from the distribution area around the patio; the scale is in a corner of the room area. The dâr are generally constructed on 3 floors. The ground floor normally hasn't housing function except the central patio which, if covered, is used as a summer living room, being fresh because it isn't invested by direct radiation, and as a warehouse or storage room in the winter. The rest of the rooms housing traditionally stables, agricultural equipment and non-perishable domestic reserves. The first plan, called assfalou, it's more private and reserved for women, shows the kitchen, the bedrooms and the storeroom for the food reserves, this part of the house is forbidden to the strangers of the family. The second floor back to being enjoyed by the guests and has direct access from the stairs, without crossing the assfalou. This plan has a covered part, where there is a living room called mesria, and a big terrace that is used to sleep on summer nights and to perform other household activities. The terrace is always surrounded by high walls, to maintain privacy from neighbors. The house looks modest, but hospitable and adapts to the need of a peasant society, once nomad, subjected to a hostile climate (warm and dry) in which the temperature changes, both diurnal and seasonal, are very marked. For these reasons, the spaces haven't a great specialization, the same room can be used as living room, dining room or bedroom, depending on needs and circumstances; the people practice the daily or seasonal nomadism into the house, which consist to live in different times of the day or of the year in different rooms of the house, to enjoy the best possible comfort conditions (Bounar & Chahid, 2004, pp. 46-47).

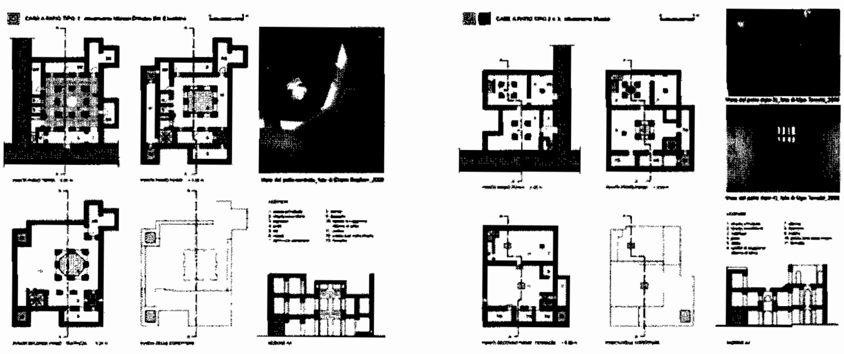

Figure 5: Examples of different dâr plans in Tissergat ksar, Drâa Valley, Morocco. (Credit by Baglioni E., 2009)

We can already see how these houses are sustainable, in the broadest sense, because responding at the housing needs and respecting the local culture closely linked to the nomadic life, link that is reflected necessarily in lifestyle and in the space occupation.

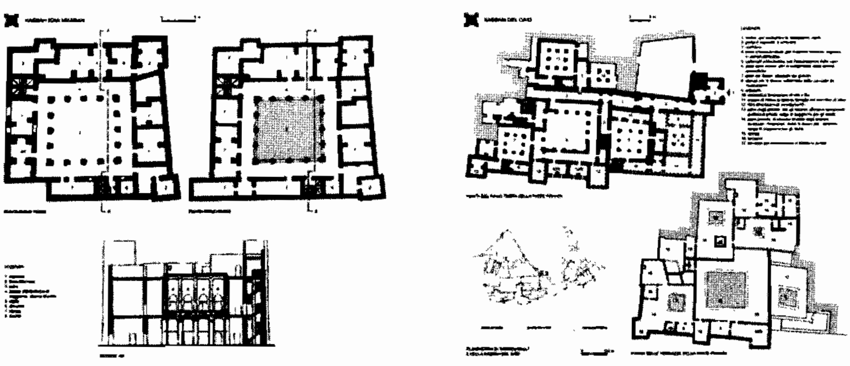

Figure 6: Examples of two different kasbah in Tamnougault ksar, Drâa Valley, Morocco. (Credit by Baglioni E., 2009)

Kasbah, in the simplest case, maintains the quadrangular type plan with central patio, but, unlike the common house (dâr) is larger, both in plan and in high (can reach 6 floors), and presents towers in the corners. Belong to large families, powerful and wealthy, often the kasbah are more articulate and occupy large areas by combining several central patio buildings. The kasbah is thus divided into different areas, private or publicly, available for the various members of the family, servants or guests, and with distinct uses (Anzalone, 2005, pp. 71-83; Biondi, 2005, pp. 157-169; Caltabiano & De Filippi, 2005, pp. 93-106; Lucci & Dania, 2005, pp. 133-144; Marrani, 2005, pp. 107-118; Sánchez, 2005, pp. 119-131).

In the Drâa Valley, characterized by a pre-desertic climate, the use of patio houses and a compact urban aggregation, represents an effective response to weather conditions, creating thus a sustainable urban system. The basic principle of buildings adaptability to the extreme temperatures is that the buildings are such that allow the highest possible ratio between the internal volume and the outer surface, condition that occurs in the ksur of southern Morocco (Abdulac, 1982, p. 2). In the ksar aggregation system, in fact, the outer surface, exposed to the sun, is limited by the adoption of buildings constructed each against other, so to have common perimeter walls on each side, except the entry side at the ground floor. At the same time, the patio is a key element for lighting, ventilation and to maintain comfortable conditions.

The patio functions as a shaft of light, limiting the direct insulation of the ground floor: all rooms of the house facing it and receive indirect light. The house is almost completely closed, only rarely found windows on the free external walls, but never on the ground floor to ensure privacy and confidentiality. The windows are quite small and shielded from wood or metal gratings, called musharabia, that filter the strong outdoor light and limit the interior visibility, however, ensuring the cross-ventilation. The patio also has a ventilation function: like a chimney pulls up the warm air contributing to the rooms cooling and creating a pleasant ventilation.

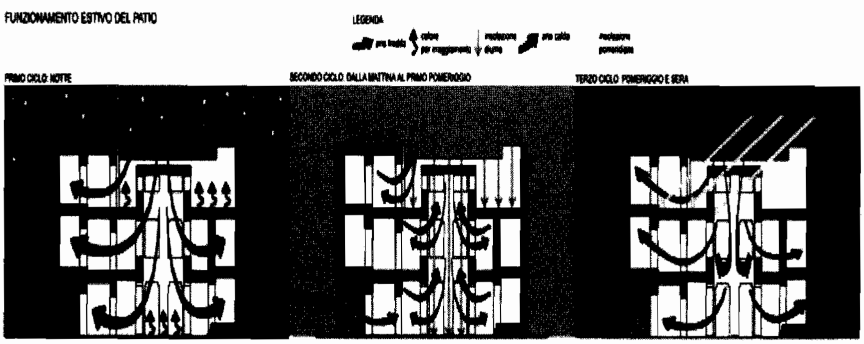

Figure 7: Patio climatic behaviour in the summer. (Credit by Baglioni E., 2009)

During the summer, the patio climatic behaviour can be summarized in 3 regular cycles that exploit the diurnal variations in temperature, higher in the pre-desert dry hot climate. In the first cycle, the cool night air descends on the patio until enter into the around room. All surfaces are cooled and are able to maintain its temperature nearly constant until the late afternoon. The patio and the roof lose, by irradiation, the heat accumulated during the day, and for this is also used for sleeping. During the second cycle, from morning to early afternoon, the patio is invested directly from sunlight, heat and gradually spreading warm air into the rooms, created so a convections motions. The patio begins to work as a chimney, drawing the fresh air replaced by warm, yet create the "breeze". Ventilation can be increased by the presence of some windows on the upper floors or, more often, opening the entrance door to let enter the cool air of the tunnels roads. The outside temperature is very high, but the thick walls (60-80cm) and roofs (40-50cm) made with row earth are excellent thermal insulators and don't allow penetrate the external heat into the house, the displacement between the external and internal wall temperature can reach 12 hours. The houses also being leaning each against other and having common walls on at least 3 sides, would be further isolated from the heat gain during the day. In the third cycle, during the afternoon, hot convection currents increase due to the heat accumulated in the earlier sunny hours, and in the late afternoon, fresh air has been expelled almost completely from the rooms. But outside the sun is weaker, the shadows are longer, temperatures begin to fall and cooler air begins to flow and get into the patio. Begins a new cycle (Al Bena'a, p. 1).

Let's see how, with some typological devices, is possible respond, in an effective and sustainable way, to the comfort living needs, even in hostile climatic conditions, especially without the use of energy expenditure. But an effective building type, if not accompanied by an appropriate choice of construction materials, often alone is not enough.

2.2 The Drâa Valley earth building techniques (Morocco)

In the traditional building technique of the Drâa Valley, the major role is played by the earth material, used in many different situations, which proves to be the most suitable material for an effective response to warm dry climate of the place.

The masonries techniques used are the rammed earth, called alleuh, and the mud brick, called toub, used separately in different parts of the building. Although this techniques are known and spread throughout the World, their implementation demonstrates a local cleverness which allowed at the population to adapt and protect themselves against the toughest aspects of the pre-Saharan climate.

The rammed earth is a technique that consist to compact layers of damp earth in a wooden formwork. This technique allows realize a very tick (40-100 cm) continuous bearing walls. The masonries runs proceeding horizontally until the completion of the entire perimeter, after an appropriate drying time (depending on climate, but not less than one week), necessary to prevent deformation or collapse of the wall, goes to realize the higher level; the building is then lifted for later “layers". This construction system performed by shifting one formwork, block to block, involves the adoption of an almost constant thickness of the wall along the perimeter and, generally, even over the whole height. As for masonry buildings, particular attention should be in the scarf realization to ensure mutual collaboration between the blocks, between walls or between walls and partitions. The formwork may have varying dimensions, in the Drâa Valley has an average size of 200 cm in length, 80 cm in height and a width varying from 60 to 100 cm depending on the height of the building; the height of the plans depends on a finite number of rammed earth blocks. The rammed earth walls behave monolithically, the mass gives stability and strength but low ductility for the response to the earthquake. Thermal inertia is directly proportional to the thickness, these walls are therefore particularly suitable for very hot climates or characterized by extreme temperature changes, as in the pre-desert climate. For the rammed earth, the material preparation and its implementation coincide. The material transformation is totally in the yard and requires technical knowledge that is acquired through experience, since the wall performance will depend entirely on the choice of earth, by mixing and its implementation (Baglioni, 2009, pp. 61-67 & 96-105). The earth required for the rammed earth must be well graded, with gravel, sand, silt and an optimum clay percentage of 20%. The earth is mixed with water in varying percentages, between 4 and 18%, according to the type of earth used, and let repose for at least 2 days before being placed in work. The cohesive effect isn’t entrusted only to the clay but also to compaction during implementation. The rammed earth geographical diffusion and the luck along the time are due at least three factors: the ease of finding a suitable soil type, the low amount of water compared to other earth construction techniques or concrete; the reducing use of other natural materials like wood. By contrast this technique requires a large amount of earth and long lead times due to drying.

Figure 8: Rammed earth masonries, Drâa Valley, Morocco. (Credit by Guidoni E., 2007)

The mud bricks are sun-dried blocks of earth, shaped in wooden molds. The block sizes vary widely according to local building traditions, though usually resort to a width equal to half length and height equal to a half width. The earth must be carefully selected, rich in clay (at least 40%) and without gravel. It adds a lot of water until obtain a malleable and plastic dough that is left to rest for at least 2 days. Due to the large amount of clay and water, the mixture is subjected to a strong withdrawal during drying, to limit the effect is generally added straw or other fibers (vegetable or animals). The mud bricks are formed by hand into the molds and allowed to dry in a large sunny area, turning on all sides; once dried can be stored and used later. The drying phase is critical for the mud brick success, it must be smooth and would be better not expose them to direct radiation at least in the early days; the drying times vary according to climate and seasons, from 2-3 days in summer and 10-15 days in winter.

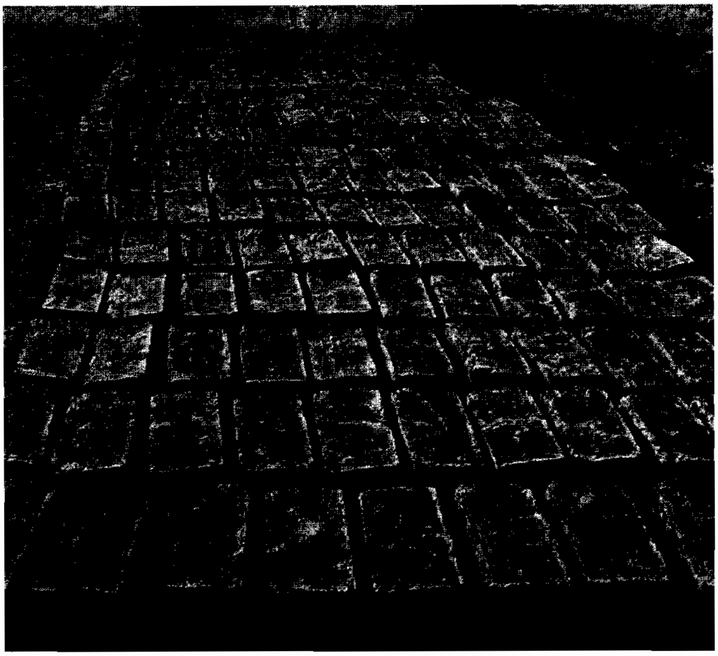

Figure 9: Mud brick sun dried, Dades Valley, Morocco. (Credit by Baglioni E., 2009)

The mud brick wall realization follows the same construction rules of a traditional masonry: the adobes are put in place, at 2-3 or 4 heads, with a earth mortar generally achieved with the same dough; you can build relatively thick walls (min. 30 cm) with a strong inertia, but from a low response to the earthquake, behaving so fragile. The vegetable fiber addition to the mixture improves the material tensile strength, but doesn't make it structurally resistant to this effort. The mud bricks walls are characterized by high thermal inertia due to the high specific gravity and therefore turn out particularly suitable in the areas with high climatic temperature range. In the Drâa Valley the mud bricks are used where the rammed earth masonry is difficult or inappropriate: in the upper floors, where carry the dough is difficult and tiring; as a string course to complete the thickness of the wooden floor; above the doors and windows lintels where press the earth isn't recommended, but is in the pillars and walls of the patio that the mud bricks plays its prince role, pushing up its bearing and decorative capacity (Baglioni, 2009, pp. 68-71 & 106-119).

In the earth masonries, whatever they are, a key role is played by basements, preferably on stone or brick, which have the principal function to limit the capillary rise of moisture from the soil (Baglioni, 2009, pp. 88-95).

In the Drâa Valley, the earth is an essential element of almost every technological solution, plasters and mortars are made with earth, floor and roofs are made of palm wood structure, which is superimposed a reed and various layers of pressed earth. Regarding the floor plan we have two layers of clay earth, both of thickness of about 5 cm, the first is dry and the second is wet. The roof, having to perform the protecting function of the entire building from the weather, differs in quantity and quality of the earth layers and, thus, in the thickness. The package consists of three layers of clay, each of thickness of 5 cm, with different functions and made with different mixtures. The first layer is made with a mixture similar to the rammed earth mixture, so humid, but prepared with a finer earth; the second layer is dry and its function is to absorb water infiltration when the top layer doesn't had a perfect seal. The last layer, in addition to finishing function, must be waterproof, it's therefore done with a moist mixture of earth and lime or earth and straw. Lime is a natural stabilizer which makes the clay waterproof and, once dry, makes the dough more resistant. The roof needs frequent maintenance because it's subject to degradation caused by rain, wind and sandstorms. Maintenance is performed every 4 or 5 years, creating a new layer above the existing finish. (Baglioni, 2009, pp. 141-151).

The date palm is the backbone of the pre-Saharan oases ecosystem and marks the border between the Sahara and the Mediterranean culture. As the only wooden materials usable in construction field, is used to achieve the doors and windows lintels and the horizontal structures of the floors. Its mechanical performance are low, because its trunk consists of bundles of parallel fibers that, subjected to loads, doesn't ensure effective mutual cooperation and suffer intense inflections. The problem is then content and controlled maintaining the lights relatively small, generally 2 to 2.5 m (up to 4 m); dimension that becomes a real module for any building construction (Baglioni, 2009, pp. 84-85).

Let's see how all the materials used are natural, readily available on site and present in large quantities.

The raw earth housing yard are traditional and managed by small artisan "company" consist of a master chief, called maâlem, and a variable number of workers or laborers, but no more than a few units. The working tools are proportional to the type of yard, traditional and craftsmanship (Baglioni, 2009, pp. 73-79).

Sustainability of these techniques is also in the use of local workers and often in the family participation at the construction process.

Unfortunately, in the Valley, we are seeing a gradual abandonment of row earth patio homes in favour of houses increasingly built with concrete blocks, which retain, however, the patio type. The use of cement is spreading because it's considered index of development and progress, although, in this context, is often the bearer of completely inadequate results to the local environmental conditions. The concrete, in fact, unlike the earth, doesn't guarantees the maintenance of a climatic comfort inside the home, creating rooms hot in summer and cold in winter. These data are demonstrated by the fact that the inhabitants of the concrete houses suffering from rheumatism in the winter and move into the earthen houses in summer, because are more fresh.

3 The Benefits and Potentiality of The Earth Construction Material

At the point of views of sustainable building, of energy saving and safeguarding of the planet, the earth, too often underestimated because it's considered a poor material and bound only to the rural environment, presents, on the contrary, many advantages that should help his re-entry among contemporary building materials. Firstly, it's a readily available material on almost all the Planet, as witnessed by its wide use in the vernacular architecture of the most different regions. Although there has been made, in relatively recent times, studies on optimum earth used for construction, the large existing built heritage, often centuries old, shows the great adaptability of earth to be used for constructive purposes. The man, moreover, has always been "engineer" to improve the performance of the available material, making mixtures between different types of earth or additive the mixtures with other "ingredients" mainly from natural sources (straw, vegetables and animal fibers, rice hulls, sawdust, dung, succulent plants extracts, casein, lime, graphite, bitumen, cement, etc.). The earth is an ecological and completely recyclable material, is reusable both in construction that maybe in the agricultural field, in fact, the earthen buildings, if left to themselves, come back to be earth. The earth allows a great variety of different technologies (rammed earth, mud brick, wattle and daub, cob, straw-earth, wood-earth, etc.) all providing low water-consuming for the dough production. The production and installation of earthen techniques, don't require special skills and can therefore be made on site and using local human resources.

This has many advantages: a low product cost and a low energy consumption for its production, a minimum consumption of non-renewable resources, but especially the opportunity to train local workers and so create new skills or new jobs. Another advantage is the possibility to have a economic constructive process and to ensure the maximum respect of the local building techniques, achieving a better integration of new structures in urban and social context, avoiding the imposition of new forms and new systems. The earth also provides very good climatic performance, acting as a natural temperature and humidity regulator. The material inertia makes the heat absorbed from the wall are distributed in the interior within a considerable displacement time: at a constant temperature the effect isn't evident, but in climates with high day-night temperature excursion the heat accumulated during the day is dispersed at night and the morning the wall is cool again, the phenomenon is also reflected in the season. The earth is also a humidity regulator, able to absorb the air humidity and dropping it when the environment becomes drier. These properties mean that the rooms inside earthen walls, are healthy and have comfortable and constant climatic conditions in all seasons. Finally the earth has a good resistance to the fire and can easily be "restore" because it's enough to produce a earth mixtures similar to the originals for compensate any cracks.

Unfortunately, the prejudices on this material are still very rooted because it's considered a vulnerable materials. In fact the only earth vulnerability is water, which can be easily solved with the implementation of appropriate bases and covers, with the use of efficient rainwater removal (guttering and downpipes), and with the possible addition of "stabilizers" materials to improve the performance. A key role, in the protection to the water, is played by the plaster, also made with clay, which must be frequently maintained and renewed.

4 Conclusions: The Actualization Of Traditional Building Techniques

Is undeniable that the traditional homes, alone, they can't cover some new social and housing demands, but the solution isn't necessarily in abandoning or on imposing different lifestyles related to the modernity stereotypes. A clever solution would be respect local diversity, recognized as adequate and sustainable, continuing the "natural" process improvement to adapt to new needs (social, environmental, economic, regulatory, etc.).

As regards new buildings, in this quest for sustainability, during the design and planning phase should be used functional principles and technological building systems that can reduce substantially the energy consumption and the waste generated from the production, construction and life of the building, should also plan the disposal step and the recycling and reuse of materials. It's important that each house is worthy and healthy, that are used healthy materials and not harmful to human health, which takes into account the comfort conditions (lighting, ventilation, humidity, sunshine, clean water, sewer, disposal waste, etc.). and that you respect the cultural, economic and social diversity.

The earth is a material that lends itself well to these demands because respects the environment, is fully recyclable, prevents the relationship with the trade monopoly, allows greater flexibility in the architectural choices, it can maintain and renew the traditions and the expressive languages enough to lend itself to the self-construction. The limit dictated by the long execution times can be killed with the help of semi mechanical processes, such as the use of pneumatic compactors for the rammed earth construction or manual presses for the mud brick production. These methods, decreasing the water amount needed, considerably reducing the natural drying time and make the raw earth a competitive material on the building market. One factor to be reckoned is the economic, because building a house with traditional material costs about half of a cement house and the cost is further cut down if you used the self-construction.

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