Foreword

This book is a reflection on the processes and ideas that I have applied to the design of my graduation project. As with most architectural projects, there is a continual refinement of ideas and motivations. I have tried to capture the essence of my work in a narrative based process in my attempts in finding architectural meaning in the context of the design.

The aim of my project has been a conscious decision to create a public sphere within the context of the Saharan desert. The natural elements, sun and water are key factors to my design. The daily and seasonal rhythms are contributors to the shaping of the design. This book is a collection of ideas, quotes and a collage of my ideas.
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Expedition to Aït Benhaddou

Windey roads through the Atlas mountains, deep crevaces and single laned roads. It is a strange feeling to move from snow capped mountains to the dry sandy plains of Ouarzazate.
“Architecture is the learned game, correct and magnificent, of forms assembled in the light”
- Le Corbusier
Courtyards

The daily shift in the shadows from east to west occurs at all times of the year, but the shadowing of the north and south portions of the court varies with season. The result is a kind of segmentation of each court into spotlighted areas where it is easy to imagine ritual activities taking place at different locations in the courts at different times of the day and year.
Ait Benhaddou is abound with steps and differences in heights. The hill that the town has been built on, allows for moments of intrigue and hierarchy of public and private thresholds.
Alleyways

The public spaces of the city. The word for wall in Arabic is ‘hamsayeh’, the words direct translation to English is: “the shade which I share with my neighbour”. The deep and shaded alleyways offer a cool environment, sheltered from the harsh African sun.
A town built only with the use of rammed earth resembles a monochromatic environment that blends in so well with nature that it creates an indivisible relationship with its surroundings. As time weathers the earthen walls, the town once again becomes part of the desert.
Without water, Ait Benhaddou would never have been able to replenish the caravans of camels of the trans African traders. Water canals, and water pits are essential infrastructure for agriculture, and survival of the people.
Gateways

The town was built as a defensible village (Ksour). Gateways act as essential architectural elements to define the change of space. It is a symbol of power and control.
There is never one way of crossing the river. The river's movement and depth is dynamic and changes through the seasons. New patterns of crossing are made daily. Sand bags or stepping stones are essential to ensure dry feet.
Culture and the people

Aït Benhaddou is a Berber settlement. Today the town is predominantly Islamic. The people are friendly and cheerful, a cup of sweet mint tea is always at hand for thirsty travellers. The people are traders by nature, so be prepared to swap clothing or shoes for trinkets and desert silver
The new town is mostly constructed with combinations of concrete and rammed earth. Very little time or effort is put into the renovation of the old town, most of the renovation is just for curio shops along the walking paths.
Material Testing - Moisture Test

Water is the achilles heel of rammed earth. Recent developments with latex based coats has helped to prolong the life of rammed earth walls. Flexible waterproofing coatings protect the facade whilst still allowing for thermal expansion and shrinking of the material.
Artificial

Gateways, towers, and movie sets have become common additions to the site. The movie industry has left its stamp on the local architecture. Hollow wooden studded adobe walls and concrete monstrosities hide between the earthen architecture. Unesco has put a stop to additions since the 1980’s, although many remnants can still be seen and are often mistaken for the original Ksour
Additional Photos
1. Entrance to Ksour via Orchard
2. Oldest building (Recently renovated) used to be a grainary
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Solar Study

of Aït Benhaddou

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28 June 2013

Abstract

This paper examines the solar and lighting conditions of the ancient Moroccan city, Aït Benhaddou. The objective of the paper is to make clear what effect the urban morphology has on the living conditions of its inhabitants. Three elements have been focussed on for the analysis of the city, namely: Building form, lighting conditions and reflective properties of materials used. The result is a critical assessment of the housing situation, and how the use of a newly introduced material - solar made glass, can improve the current living conditions.

Key words – Solar radiation, solar availability, Aït Benhaddou, Lux measurements
Long duration of sun in the summer can lead to the surface receiving as much as 10 hours of sunlight a day. Although the incident angle of the early morning sun is relatively low, it rises to the normal incidence during midday and the temperature of the roof will keep rising.

In Ait Benhaddou, the earthen buildings have a layer of mud as a roofing material, and are built with a timber support structure. Local Tamarix wood beams and reeds are used for making the ceiling of the buildings. The low thermal emissivity of the wooden ceiling helps protect the interior from further radiation effects.

1.3 Lighting of the Ksour

The Ksour (ancient Berber city) reveals a strong urbanity which differs from other forms of rural settlements. This is due to the spatial and structural morphology. It obeys a geometric framework from which all its components are developed and organized on a square grid in all types of spaces. The grid can be explained by the span limitations of the wood beams across the rooms, spanning never more than two or three meters. This framework is not only two-dimensional, it continuous vertically throughout all volumes. All the buildings grow organically with multiple floors that match each other’s heights. This leads to a complex network, where the interweaving of buildings is connected by the narrow passageways.

The shape of the village is regular, generally, with the facades at right angles to one another. The size of the community is directly proportionate to the housing sizes.

It is the small 3x2 meter spans and narrow alleyways that create the low range of lighting conditions within Ait Benhaddou. On site, measurements with a lux meter were taken. All studies were done at 14:00 in the afternoon over a period of three days. The diagrams indicate the lighting levels are extremely low, too low for any indoor working activities. The table on the next page shows appropriate lux levels for common areas in buildings.
<table>
<thead>
<tr>
<th>Areas common to most buildings</th>
<th>Lux (lm/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entrance hall, lobby, waiting room</td>
<td>200</td>
</tr>
<tr>
<td>Enquiry desk</td>
<td>500</td>
</tr>
<tr>
<td>Corridor, passageway, stairs</td>
<td>100</td>
</tr>
<tr>
<td>Atria</td>
<td>50-200</td>
</tr>
<tr>
<td>Changing room, cloakroom, lavatory</td>
<td>100</td>
</tr>
<tr>
<td>Rest room</td>
<td>150</td>
</tr>
<tr>
<td>Canteen, cafeteria, dining room</td>
<td>200</td>
</tr>
<tr>
<td>Kitchen</td>
<td>300</td>
</tr>
</tbody>
</table>

Figure 5: CIBSE Lighting Guide (LG02)

Figure 6: Shadow Range of Aït Benhaddou
Another simple example shows how low the lighting levels are within the houses. Standard practice is that the window area of a wall should at least be 10% of the wall area. Here you can see the area is a low as 2%.

1.4 Reflectance of materials

On site, the lux values of all the materials were taken inside one of the courtyards. By using the following luminance reflectance equation, the following reflectivity of the materials could be calculated:

Material Coefficient test at Hassan’s House 14:13 08 December 2012
Rammed Earth – 63.6%
Stone + mud wall – 79%
Cement floor – 35.6%
Wood – 79%
Straw – 80%
Pottery – 53.9%
Carpet – 37.5%
Tiles – 36.6%
Stone floor – 53.9%
Lighting Values of Streetscapes in Ait Benhaddou - Extruded
Ground floor LUX values, all measurements taken at 14:00 in the afternoon.

First floor LUX values.

On site calculations with a lux meter allowed for accurate collection of lighting levels in the streets and within the buildings. These images show the process of digitizing the on-site measurements into software, where the values could be assessed more thoroughly.
1.5 Conclusions

Conclusion on Form:

The nature of the urban typology of Aït Benhaddou still resembles the form of an ancient fortified city. The solar study of Aït Benhaddou reveals that it is not as much the housing typology that is a strong climatic contributor, but rather the conglomeration of buildings that protect the city from the extreme sun exposure. Alternative organic forms should also be researched. Flat roofs are more compact, whereas organic shapes have larger volumes. Designing larger spans and organic shapes allows the buildings to cool faster and disperse the heat load of the building. What can also be noted is that the living conditions in Aït Benhaddou have become unbearable for the inhabitants, and it is a sign that the housing typology although local and vernacular, suffers to keep the inhabitants satisfied. Raised standards of living and a desired modern housing needs has led to the old town becoming less appealing to its inhabitants.

Conclusion on Lighting

The interior lux values at Aït Benhaddou are dismally low. The reasons for small windows are in accordance to rammed earth weak tensile strengths as well as past fortified defences preferred small windows. Aït Benhaddou acting as a fortified city. Thirdly, the cities function has for a long time been out-dated. Solar glass could drastically increase structural spans and improve lighting conditions. As the solar radiation is high in Morocco, diffuse light could be an excellent alternative to the current small windows. Heat loss is small because of small window openings.

Conclusion on Reflectivity of materials

Rammed earth varies in colour depending on the mud used for construction, but is ultimately brown or red in colour. The low reflection of the materials also cause the interiors to be very gloomy and dark. Improving the reflection of the interior spaces will allow for better internal light reflections. Materials with higher reflectivity rates can be used to capture more light into the spaces.

1.6 Recommendations for the graduation project / further research

The production of solar glass is a very new field of research. Although there are large amounts of research done on solar concentrators in the desert or properties of glass, there are virtually none that combine the two fields together. It is the challenge of this graduation plan to find appropriate application for solar made glass. As this is a dual project, where the focus of the other students work is on structural applications, my research will cover aspects of sustainable building design. The main principles for design will be concerned with urban morphology of the earthen architecture (the form) in relation to the solar conditions, and how the new material can be used within this context of extreme hot desert conditions. The next research paper will discuss the properties and applications of this new material.

1.7 Calculations

Sol-air temperature \((T_{\text{sol-air}})\) is a variable used to calculate cooling load of a building and determine the total heat gain through exterior surfaces. It is an improvement over:

\[
\frac{dQ}{dA} = h_o(T_o - T_\text{a})
\]

Where:

- \(dQ\) = rate of heat transfer [W]
- \(A\) = heat transfer surface area [m²]
- \(h_o\) = heat transfer coefficient for radiation (long wave) and convection [W/m²K]
- \(T_o\) = outdoor surroundings' temperature [°C]
- \(T_\text{a}\) = outside surface temperature [°C]

The above equation only takes into account the temperature differences and ignores two important parameters, being 1) solar radiative flux; and 2) infrared exchanges from the sky. The concept of \(T_{\text{sol-air}}\) was thus introduced to enable these parameters to be included within an improved calculation. The lower formula results:

\[
T_{\text{sol-air}} = T_o + \frac{(a \cdot I - \Delta Q_{ir})}{h_o}
\]

Where:

- \(a\) = solar radiation absorptivity (surface solar absorptance or the inverse of the solar reflectance of a material) [-]
- \(I\) = global solar irradiance (i.e. total solar radiation incident on the surface) [W/m²]
- \(\Delta Q_{ir}\) = extra infrared radiation due to difference between the external air temperature and the apparent sky temperature. This can be written as \(\Delta Q_{ir} = F_i \cdot h_{ir} \cdot \Delta T_{e-sky}\) [W/m²]

The product \(T_{\text{sol-air}}\) just found can now be used to calculate the amount of heat transfer per unit area, as below:

\[
\frac{dQ}{dA} = h_o(T_{\text{sol-air}} - T_\text{a})
\]

An equivalent and more useful equation for the net heat loss across the whole construction are:

\[
\frac{dQ}{dA} = U_c(T_i - T_{\text{sol-air}})
\]

Where:

- \(U_c\) = construction U-value, according to ISO 6946 [W/m²K].
- \(T_i\) = indoor temperature [°C]
- \(\Delta T_{e-sky}\) = difference between outside dry-bulb air temperature and sky mean radiant temperature.
\[
\frac{q}{A} = \frac{U_c(T_i - T_o)}{h_o} - \frac{U_c[a \cdot I - F_r \cdot h_r \cdot \Delta T_o - \text{sky}]}{h_o}
\]

[Ashrae, 1974]

Luminance reflectance equation

\[p_t = p_s \times \frac{L_t}{L_s}\]

where

\[p_t\] - is the reflectance of the target, i.e., the unknown surface.
\[p_s\] - is the reflectance of the standard
\[L_t\] - is the luminance of the target surface
\[L_s\] - is the luminance of the standard surface

1.8 References

- Domes and Solar Radiation, Dr. Andrew J. Marsh, ISSN: 1833-7570, Issue No. 002, August 01, 2006

Shadow range at different scales. The top images show the range of shadows of the whole village. The middle two images show a typical Berber house; note here how the alleyways are dark. In the bottom images, the shadow range is of a Kasbah. Here the building receives large amounts of light because of its height, but both the internal courtyard and public courtyards are kept shaded.
Supplementary Report

Site Analysis Aït Benhaddou

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Location of project

Macro Scale map of the important cities of Morocco
PART 1 - THE MACRO CONTEXT

3.1 General Introduction to Morocco

Morocco was part of the former Maghreb region, Maghreb meaning ‘West’. Morocco is the most North Westerly country of Africa with a population just shy of 36 million inhabitants. The majority of the population live in the more temperate coastal regions of the country. The country is still ruled by a constitutional monarchy with an elected parliament, but in February 2011, the Arab Spring protests started, calling for new political reform and the proclamation of a new constitution. The protestors did not succeed and the country is still ruled by the monarchy.

Islam is the main religion, where the official language is Moroccan Arabic. In more recent history, during the 1930’s French and Spanish protectorates brought modern literature and European influences to Morocco. Today French language has become the predominant language after that of Arabic and Berber language.

Morocco has a Mediterranean climate, but the weather conditions become extreme towards the interior regions of the country. On the interior side of the Atlas Mountain there is an extreme change in weather as the barrier/shelter effect of the mountain systems makes the adjacent areas very dry and exceptionally warm. From the interior of the Atlas Mountain, the landscape turns to desert, with a green belt of oasis’s found close to the Draa Valley.

Historically, the southern region of Morocco formed part of caravan routes where many traders moved through the Sahara desert for trading with the Sub-Saharan empires. People were predominantly nomadic, living a life trading goods throughout the Saharan region. Many outposts and towns developed around the caravan trading routes. Ksour’s or otherwise referred to as fortified villages or forts are strewn along the reaches of the Atlas Mountain. They were the mark of wealth by the families who were successful tradesmen. They are all made with rammed or adobe earth and many are still intact and used, some predating from the Roman Empire. With the introduction of larger shipping vessels and industrialization of Europe in the 1800’s, the caravan routes became obsolete as the new shipping trades strangled the need for cross African transportation. Today, some of the Kasbah’s are protected under the authority of UNESCO’s world heritage list. The fortified earth village, Aït Benhaddou has become one of the popular tourist attractions in Morocco and has been used often for films and scenic movie backdrops, owing to the very unique architectural style. A few rural farmers still live in the region, although the old villages are left by locals who move into newer cities with better amenities.
3.2 Topography of Region
The terrain of Morocco varies from the coastal plains in the North to the interior mountains with large areas of bordering plateaus. There are four distinct geographic regions:
1. The Rif Mountain – parallel to the Mediterranean coast
2. Atlas mountains, extending across the country southwest to northeast
3. An arc of wide coastal plains
4. Lowlands South of the Atlas, which merges with the Sahara desert

The Atlas Mountains comprise of many intermountain valleys. Current environmental issues are land degradation and desertification, with water supplies often contaminated with raw sewage and mining runoffs.

3.3 Early Urbanization: The caravan Routes
The Sahara has had a drastic change in the last millennia. By 7000 B.C. most of the land was pastoralized by tribes, herding sheep and goat. With the introduction of cattle around 3500 B.C. the desert has slowly expanded due to overgrazing and increase pressure of human settlement. Pre-colonial trading was done by caravans of camels. These caravans averaged approximately a 1000 camels and some were recorded as large as 12000 camels strong[Reference]. The need for trading was due to the rise of the Ghana Empire in the
Middle-Ages. Mediterranean countries were short of gold where the west African countries were in need of salt. Another imported commodity for trading was the slave trade. It has been estimated that as many as 9 million slaves were imported to the North to serve as domestic servants or soldiers. The first caravan routes started operation around the 3rd century A.C. with the last of the routes terminating in 1933. The Trans Saharan trade was very prosperous until the 15th hundreds with the battle of Tondibi in 1591-2, when troops from Morocco attacked Timbuktu, Gao and other important trading routes. The disruption led to a decline in trading. Trading continued, but at a reduced rate. In the 1800’s many railways were built, which were subsequently destroyed by disputes between countries and later during the First World War. Today, the shorter routes are still in use. There are future plans from the African Union and African development bank to support the ‘trans-Sahara Highway’ from Algiers to Lagos via Tamanrasset, to try and stimulate the trans-Saharan trade again.

The floods of 1989 triggered the departure of the majority of the ksour’s population towards the right bank of the Oued el-maleh, with a hundred households against seven remaining within the walls of the Ksour. This movement of the population from one bank to another - already underway since the early 1970s - has formed the new village. The old Ksour had no proper infrastructure, absence of an adequate crossing, especially during floods. This left the people living in the Ksour with a sense of isolation and marginalization reigned at the old Ksour.

But the phenomenon of abandonment – evident in most of southern Morocco’s Ksours are part of a social movement of the Moroccan population urbanization stimulated by the search for a better way of life that they no longer find in the Ksours. The original function of the old village was one of a defensible village typology and has today become an obsolete association.

### PART II – MEDIAL CONTEXT

#### 4.1 Urban traditions, distribution and population growth

[It must be noted that the town of Aït Benhaddou Benhaddou can be studied as two separate areas. The old Ksour, and the New Town. The river divides the new and old town. For an concise study, the main focus of the site analysis has been on the old Ksour.]

#### 4.1.1 The abandonment of the Ksour

Town population is roughly 3000 people, mainly located in the village across the river (Wadi el Maleh) near the road leading to Ouarzazate. Seven households with approximately fifty people still inhabit the old Ksour.
From his observations, it can be deducted that Ait Benhaddou is a mixture between the old Berber Ksour villages, and influences of Islamic culture. There has been major redevelopment of the city in the 1600's, so it almost impossible to establish what the city’s layout was before this period. Ait Benhaddou can be considered to be a dual city as it pertains associations with the local berber people and islamic influences.

There is a fascinating and close relationship between all the ancient cities of Saharan African city typologies, although the main urban traditions that can be found in Ait Benhaddou are; the close relations between family living and immediate surroundings to the Mosque as the epicentre of the community life. Trading is still very prominent in the culture of the people, as many still work as traders rather than subsistent farmers or craftsmen. The location of the village is such that there is hardly space for large communal areas. This is uncommon as most ancient Moroccan cities, had a medina that often functioned as a
central node of the cities or villages. In the Ksour, courtyards offer semi-public spaces, where families or friends can congregate. It must be mentioned that the Ksour of Aït Benhaddou Benhaddou is built as a defensive village. The Ksour has fortified walls, narrow alleyways and dark spaces to protect the inhabitants from the attack of any invaders. Today these spaces are counterproductive for the inhabitants.

4.2 Basic Infrastructure and Urban Commodities

The old Ksour of Aït Benhaddou Benhaddou has a very basic infrastructure. It has only recently acquired plumbing and newly paved alleyways. Due to restrictions from UNESCO, the old Ksour is not allowed any electrical conduits as it will destroy the existing facades of the Ksour. The ease of building new buildings with modern amenities, with electricity and plumbing has caused many of the inhabitants to move across the river to build in the new town. The Ksour has a very old underwater canal that runs through the city walls. Potable water comes from the town of Ouarzazate via an underground pipeline. The town is heavily depended on tourism, and therefore the main urban commodities are in the form of services, hotels, restaurants. Trading and selling of curios and other local Berber craft is the only other local commodities sold.

4.3 Architectural Heritage, spatial organization and temporal patterns

“The Ksour of Aït Benhaddou is presented as a set of compact and closed living quarters, attached to the south side of a hill. The location suggests builders tried to avoid the icy winds from the North (Atlas Mountains).”

Translated from: 1 H. Terrace, op. cit. (P93) quoted by JL Michon, op. cit., p.48

Site selection was likely governed by several factors: the need to monitor the trading routes, direct access to the river, and a defensive village wall for protection against potential enemies. At the top of the hill, remnants of fortifications can still be seen. At the periphery of the Ksour, there are two cemeteries; one reserved for Jews and one for Muslims.

The last hundred years of development at the old Ksour have had the most drastic urban and cultural changes. Before this period, any development happened within the walls of the old Ksour, but with new modern technologies and new amenities, it was easier for people to live comfortably outside the old city walls.

The spatial organization of the Ksour is based on two major elements:
1. Public
2. Private
The first is public spaces. Here the spaces are used for meetings and festivities of the Jmaa Mosque and Koranic school. The roads, narrow and covered - become extensions of the public spaces in the old town.

Private space is constituted by the clustering of houses. They are of two types:

The first - about fifty houses - are often at a single storey height, without decoration and matches the topography of the hill. They were home to the majority of the Ksour’s population, and do not possess great levels of architectural aesthetics.

The latter is formed by a set of six Kasbahs (houses of affluent trading families) flanked by towers and are richly decorated. They are located in the lower regions of the village. It is somewhat unclear what the socio-political relationship was between the different economic classes in the community. It is presumed that the larger Kasbahs were at the foot of the hill for its proximity to the oasis’s and beautiful gardens. (Land that had much higher property value as it was situated closer to water canals)

The old village has many levels of containment, the village surrounded by walls, house blocks are wrapped by narrow alleyways and courtyards, and then the building themselves focus inward on a courtyard axis.

Many of the public spaces and family units have similar characteristics to that of other African city developments. Many examples of Islamic and Berber cities within Morocco and Northern African countries follow similar spatial and temporal patterns.

The spatial patterns are often associated with organically growing cities, with densely packed spaces, which allow for rich societal interactions between individuals. There are many advantages to these tightly knit cities. These cities show exemplary methods of defensible space and logistical patterns.

4.4 New Town Spatial and temporal patterns

The older settlements is a congregation of clustered houses, whereas the new town developments has lost many of its cultural identity and turning its attention to the linear road development. The new town feeds off the road as a source of income. The new houses do however still follow a building tradition of making the houses face inwards. This will be discussed in a later section of the paper.

4.5 Physical forms of the city

There are only a few major elements that can be defined by the Old Ksour:

1. Village wall,
2. Kasbah – Rich and affluent houses, castle like,
3. Housing, massing of the city and urban massing
4. Mountain side – plays a big role in the physical appearance, structure and climatic response of the town
4.6 Pattern of Land use
Water is the life of these villages in the Anti-Atlas region of Morocco. Water is the life line in the desert, and so all the usage of land revolves around the river. The old Ksour was highly dependent on the river for sustenance, and its location is proof of that. The Ksour follows the natural flood line of the river and the gardens are situated in the rich plains, so that annual water can be trapped and fed into the vegetable gardens and orchards. Interestingly enough, the new town development on the other side of the river, faces the road. The organically contained old Ksour typology has fallen away for the new town development. The new town suffers from irreversible urban sprawl, with little or no climatic or social reasoning for placement of housing, except for that it happens along the road.

4.7 Problems of People and Land
In recent decades, the vernacular architecture suffered a breakdown due to multiple factors:
- Disruption of traditional socio-economic structures;
- Emergence of modern living found more attractive for inhabitants;
- Climatic fluctuations: drought; excessive flooding
- Exodus and abandonment.
The granaries in the region are becoming rarer. Kasbahs have lost their original function and villages are plagued with poverty for the few ‘Ksouriens’ who still live in the Ksours Ait Benhaddou Benhaddou main problem is economical. With the decline of the Saharan trade routes, the old Ksour has lost its function. Its main income in recent years has largely been by tourism. It is very dependent on money from tourism from Europe and the Hollywood movie industry who often does film productions in the town. Ait Benhaddou Benhaddou has no exports, and need the income from the tourism industry. In 2011, during the Arab spring, a terrorist bombing in Marrakech, led to a decline in tourism in Morroco that year, seriously hurting the already sensitive and far away town of Ait Benhaddou Benhaddou. Urbanization is a major problem for the Ksours of the area. Whilst people leave for cities to find work, the hundreds of Kasbahs in the valley turn into ghost towns. More importantly, the loss of labour and men to work in Ait Benhaddou leaves the buildings for ruin, which directly affects the tourism industry.
4.8 Housing situation

With only seven families who still live in the old Ksour, the majority of the town's population have moved from the old town to the new. The new town offers safer (as mud structures can fail and collapse during heavy rain) housing with better amenities. The traditions of building with earth architecture are still applied in the new town. As rammed earth only costs the labour involved, it is still a trusted and used method for construction. It helps to lower the cost of new buildings by using earth as infill. There are four different styles of building with rammed earth in the new town, them all being composite buildings mixing new technologies such as concrete, plastics and electrical conduits into the buildings. What is interesting to note is how in the old Ksour, the houses would be built high, as space in the village was limited, but with the new reclamation of land on the other side of the road, buildings are never more than one or two storeys high as this contributes to higher construction costs. The new housing typology of the Berber people is almost unrecognizable, except for the addition of a corner detail on top of the roof.

Many of the local inhabitants of Aït Benhaddou Benhaddou don't have the education or capital to invest in their own businesses. The few families, who still live in the old Ksour, are reliant on solar powered water heaters and gas cookers, the living conditions are often still very rural with dark and cold interior environments.

4.9 Globalization of Aït Benhaddou Benhaddou, The movie industry in Aït Benhaddou

Morocco has been used as the stage for many western made movies in the last 50 years, and has helped to put the Ksour on the international map for its unique and ancient feel it brings to the industry. It has been a symbiotic relationship between the movie industry and the Ksour. Globalization has had an effect on the village with some of the structures built, not being part of the originally village.

There are two large film studios, Atlas and CLA studios in Ouarzazate, where additional scenes are shot away from the Ksour, and the studios even house large Egyptian and Persian statues for the film sets.

Reality is a bit warped by the industry, as that which is considered to be old architecture at the Ksour, is sometimes a western import. In recent years movie industry was not allowed to alter any of the existing buildings, but on a yearly basis many new structures are built as movie sets around the city walls and demolished afterward. Instead of the city acting as a node along a trade route, it has become part of a movie genre, where the city goes through a continual process of change acting out the different historical moments which the movie directors wish to direct. The Ksour has moved away from a self-contained fort to becoming an open theatre stage for the world.

The site is visited - according to estimates - by 130,000 people per year, or half of the visitors to the area. The daily rate varies from 700 to 1200 visitors per day. High tourist season spans the months of March, April and May, while the low season marked the month of November, December and January.
List of the movies shot in and around Aït Benhaddou Benhaddou

- Lawrence of Arabia (1962)
- Sodom and Gomorrah (1962)
- The Man Who Would Be King (1975)
- The Message (film) (1976)
- Jesus of Nazareth (1977)
- Bandits (1981)
- Marco Polo (1982)
- The Jewel of the Nile (1985)
- James Bond - The Living Daylights (1987)
- The Living Daylights (1987)
- The Last Temptation of Christ (1988)
- Arabian Nights (1989)
- The Sheltering Sky (1990)
- Kundun (1997)
- The Mummy (1999)
- Gladiator (2000)
- Babel (2006)
- Kingdom of Heaven (2005)
- Prince of Persia (2010)

PART III - THE MICRO SCALE

5.1 Location
Aït Ben Haddou
Aït (Aeeht) – Berber Tribal
Ben - Son
Haddou - family name
Translated from Arabic:
Praise be to God,

Aït Benhaddou Ben Haddou Ksour was built in the eleventh century. Its Inhabitants belong to the first fraction Aït Benhaddou Aïssa Or H’mad Which owns the Aït Ben Haddou (...) The armies of Ibn Yusuf Tachafine. When he passed through the area from the Sahara to Marrakech, As we have said before, we appointed this occasion Ben Haddou Sheikh of the tribe. As he took home the village which bore his name.

Mohamed Ben Mohamed Jamal Eddine 3
- Hassan Zakriti, Management of World Heritage Sites in Morocco, DEPA 2005

The old Ksour is gently nestled on the south western side of a mountainous region of the anti-atlas. It is sheltered from a strong Northerly wind that blows off from the Atlas Mountains. These Ksours were fountainheads for trade. They staked out their positions serving as bridges for trade between Moroccan cities, such as Marrakech, Fes, Ceuta and the famous ancient cities of Djenne and Timbuktu. The Old Ksour links the Draa Valley, the plain Tafilalet Marrakech and the collar of Telouet (Tizi n’ Telouet). Ksour of Aït Benhaddou overlooks Ouenila of the valley (1260 m). Wadi Maleh, subject to floods in the winter make the Ksour inaccessible. The position of the site is on the foothills of the southern slopes of the High Atlas and its distance from the sea make the climate very cold in the winter and a very hot, sunny and dry in the summer. The first snowfields cap the tops of the mountains from November and will not melt until the month of May. For the few occurrences of rainfall during the year, it is often heavy rain showers that aggravate soil - erosion. Farming is difficult in the areas as in winter, frosts are great, and in summer the intense evaporation leads to water shortages. The first family lived in the granary on top of the hill.
5.2 Circulation and routing
There are three entrances to the Ksour. The village was built with narrow alleyways and dark entrances to the Kasbahs to confuse any attackers. By the time invaders eyes adjusted to the dark interior spaces, it would have given the inhabitants ample time to attack the trespasser. The roads all lead down to the river. The streets act as overflows of public space from the courtyards.

5.3 The Urban morphology and the Use of Space

There are very intricate hierarchies of space within the Ksour. Spaces range from public, semi-public to more private situations. This is dealt with, the use of courtyards, alleyways, steps and different storeys of buildings. The current main gathering point is outside of the Ksour, this is very strange of the Islamic city typology (usually in the city centre), although it is possible that the previous medina might have been covered by newly built housing or in ruins. The city is heavily contained, and the change in spaces is dealt with the presence of more walls, and darker spaces, it is sometimes difficult to establish, what is public and that which is not, as there is very few inhabitants currently living in the village.

5.4 Housing patterns - The socio-spatial organization

The Ksour reveals a strong urbanity which differs from other forms of rural settlements. This is due to the spatial and structural morphology. It obeys a geometric framework from which all its components are developed and organized on a square grid in all types of spaces. The grid can be explained by the limitations of the wood beams spanning the rooms, never more than two or three meters. This framework is not only two-dimensional, it continuous vertically throughout all volumes. All the buildings grow organically with multiple floors that match each other’s heights. This leads to a complex network, where the interweaving of buildings is connected by the narrow passageways. The shape of the village is regular, generally, with the facades at right angles to one another. The housing sizes are directly proportionate to the size of the community.

1 M. Boussalh, op. cit. p.21
The Ksour is divided into smaller groups and other private meeting spaces. Both political and social areas are respectable in their location for keeping a harmonious, social and ethnic segmentation. The tradition of the Ksour is the collective idea of working towards a harmonious society. It owes its longevity and survival in a hostile desert environment to its social cohesion and community awareness of the occupants. In the nineteenth century, the area saw the emergence of new architectural forms: the gold Kasbahs - tighrem’t. Large houses had the main function to magnify the image of the new Lords or ‘qaids’.
## 5.5 Vegetation and Agriculture

Before the 19th century, affairs were managed by a village council, elected by the heads of families. The board monitored compliance of the people whether they followed the customary laws. These were mostly important for the establishment of schedules for the irrigation and tending of agricultural land. Inside the Ksour, wells and water tanks (khettara) were managed in a collective manner. This management was necessary because of the harsh climate and rainfall instability.

Agriculture is the main activity of the population. The production is all local subsistence farming, on small irrigated plots along the river with low yield. The use of modern technology is quite low. The instability of rainfall makes farming practice difficult and sometimes unsustainable. The river also has a very high saline level that affects the quality and productivity of some of the crops. All food that is not produced locally needs to be transported from Marrakech.

Local produce: Maize, grain, olives, dates, almonds, tamarix wood, bamboo reeds, pomegranate, carrots, lemons, absinthe, Lucerne.

Tamarix wood used in three different ways:
1. When they are young, for feeding animals,
2. Medium, ceiling reeds
3. Large trees, roof rafters

Large tamarix tree grows approx. for 10 years. Old Kasbahs use tamarix wood – 30km to the desert, an oasis with large tamarix forest is found.
The Ounila valley, where Ait Benhaddou is situated does not receive rain often, but the few times a month it does rain, the village is plagued by strong winds and heavy showers. The fact that builders can collect mud straight from the river for building gives it great advantage to any expensive imported material. Modernization of surrounding cities are causing major population shifts from the Ksour’s in the regions as the local inhabitants are leaving for housing with better amenities in the larger towns and cities.

5.6 Hydrology

The Oued el – Maleh River receives high amounts of water in the wet winter months, and with the melting of the snow on the Atlas Mountains in the spring time, floods often occur. Otherwise, the river is very dry over the summer period.

Main problems is access to safe drinking water. The potential water resources are low and the alluvial aquifer of the Oued el- Maleh records a fairly high degree of salinity. For the old Ksour, the only water available is located in the aquifer of Tikirt, 15 km away, yet it is a very limited capacity and already requested by the irrigation for agricultural land.

A canal is drawn one kilometre away from the river, and runs through the old Ksour.

5.7 Materials

Rammed earth is a time consuming building process and costly. The addition of rocks and straw is an easier process as the preparation of the material is faster. No costs are involved in building with traditional methods, but building is timely, hence labour is the main cost in construction.

Adobe bricks are made in the summer time. Wells provide water all year round.

5.8 Housing Typologies – The Kasbah Tradition

Two housing typologies are found in the old Ksour of Ait Benhaddou:

1. Normal Berber house usually clusters of families living together. The buildings are made with only the necessary materials. They are basic in form. Lower levels in the buildings are used as granaries and animal barns. Middle to top rooms are for sleeping. Central courtyards act as communal family spaces.

2. Kasbah – Rich, affluent families. Recognised by the four towers and internal courtyard terrace. People sleep on the terrace in the summer and in the interior during winter. Bottom floor is used for granary. One tower is always left for circulation. In the past, towers were used as lookout points that offered a panoramic view to spot invaders.

Public buildings – The Islam, has introduced the mosque as a typology to the Ksour of Ait Benhaddou Benhaddou.
5.9 Decorations

Decorations are typically Berber. Each Kasbah has its own individual symbols for the family identity/symbol. Decorations mostly used for public buildings and hotels, traditional buildings are void of decorations.

PART IV – CURRENT DEVELOPMENTS AND CONCLUSION

There are a few sites that will be upgraded in the future, although all the buildings requires constant renovations. Renovation depends on frequency of rain, (either because of rain damage, or the procurement of new river mud) Annual renovation is common, but with better building methods in the past, building could last up to 5 -10 years. It takes about 1 year to build a Kasbah.

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6.1 Conclusion

However, I think that the town is faced with a reality that is both heart-breaking and paradoxical. Between fragmentation and degradation due to the abandonment of the site by its rightful occupants, the Ksour is forever losing its original function: that of the habitat, but it creates new socio-economic issues related to its ranking in the World Heritage. As authentic village community, it only survives in the memory of generations who have lived there once before.
CSP solar concentrator options:

- **FRESNEL LENS**
- **SPHERICAL LENS**
- **PARABOLIC MIRROR**
- **FRESNEL MIRROR**
Solar radiation map of Africa. Map showing the location of Desertec company planned CSP plants. Many are currently on hold due to North African conflicts.
Calculations for water angle

These formulas help determine at what angle water will start rolling over the surface instead of dripping. This is particularly interesting as you do not want water droplets falling on the clients of the bathhouse.

\[ \pi r \gamma (\cos \theta_R - \cos \theta_A) > \rho V g \sin \alpha \]

- \( r \) is the radius of the contact line
- \( \gamma \) and \( \rho \) are the surface tension and density of the liquid,
- \( g \) is the gravity acceleration,
- \( V \) is the volume of the drop,
- \( \alpha \) is the angle of the plane.
Calculation for Yearly kw usage

for Hammam

Approx 60 000 kw/h needed to keep Bathhouse in operation
60 - 80% Thermal efficiency of Parabolic Trough Collectors, hence Approx. 40m² of Panels needed for heating of the Hammam.
Sun's Path

Heated Water to Reservoir
~70°C

Cold water pumped back to CSP
~35°C
Closed CSP System

Open CSP system

Hot water taps for internal use

Water fed from local mains
Service ducts on backwall

Basin for scooping water for washing

Hot water ~50°C

Cold water ~15°C
Conclusions 1. Shops are in dark narrow alleyways, close interaction with public and potential buyers

Conclusion 2. Thermal radiation of exposed areas are used when the sun sets, seating + sleeping
Conclusions 3. Gateways are covered, act as nodes in streetscape - Public to Semi Public
Transitions spaces are climatized, Gateways and ‘gaterooms’
Types of Earth Construction

Climate data of Ait Benhaddou
Concept development and Design
What is a hammam?
Plan of the Old Baths at Pompeii (Overbeck.)
Roman Bathhouses
Figure 19
The bath: water supply and drainage
Traditional Bathhouses - Turkey
Atrium

- Bath Master’s room

Apodyterium (Dressing room)

- Frigidarium (cold bath)
- W.C.

Tepidarium (Warm bath)

Caldarium (Hot bath)

Laconicum (Sweating room)
As seen in these paintings, the bathhouse has a strong sense of community gathering
- Jean Auguste Dominique Ingres
Les ruelles sont ventilées par de larges poêles de lumière, dans lesquels le vent s’engouffre, et des poêles plus étroits, par lesquels il ressort.

La carte blanche sur le dos de l’image est une illustration schématique qui présente une partie du village rural du Mati, en Libye, nommé à la fouille il y a 300 ans. Du fait de sa situation exceptionnelle, elle illustre les questions cruciales, en particulier d’une planification urbaine exceptionnelle.
Instruments for collection of site data

- LUX METER
- GPS Trackers
- SLR Camera
- GoPro for aerial photography

Equipment taken on site analysis of Aït Benhaddou. Some of the specific tools are, LUX meter, Laser meter (not included in photo), GPS trackers and SLR Digital Camera.

GPS Tracks. The Purple line indicates a route following the river to the neighbouring Kasbah (10km away). The blue line represents a track through the new town across the river into the old Ksour.
Alleyways

Warping
4 - 1

Non directional paths, intersected by public spaces

Crossings
Non directional paths, intersected by public spaces

Islands

Island Hopping

Clustering

Isolated
Shadowplay

- Bridging the Kasbah

Growing Freedom

- Contour flooding

Abstract disconnected shadows

Overflow

- Pebble and levels

- Cascade
Public Sphere

Collective Sphere

Western vs. Tradition

Public Gardens

Canalising

Oasis Grouping

Collective filtering

Linear canalising
Islamic Prayer Times

Fajr (pre-dawn): This prayer starts off the day with the remembrance of God; it is performed before sunrise.

Dhuhr (noon): After the day’s work has begun, one breaks shortly after noon to again remember God and seek His guidance.

‘Asr (afternoon): In the late afternoon, people are usually busy wrapping up the day's work, getting kids home from school, etc. It is an important time to take a few minutes to remember God and the greater meaning of our lives.

Maghrib (sunset): Just after the sun goes down, Muslims remember God again as the day begins to come to a close.

‘Isha (evening): Before retiring for the night, Muslims again take time to remember God’s presence, guidance, mercy, and forgiveness.
Daily Activities

- **Fajr**: 05:00 AM
- **Dhuhr**: 12:00 AM
- **'Asr**: 15:00 PM
- **Maghrib**: 19:00 PM
- **'Isha**: 22:00 PM

**Work Activities**
- 600kw/h
- 800kw/h
- 1000kw/h

**Personal Activities**
- 600kw/h

**Eating Activities**
- 600kw/h

**Social Gathering**
- 600kw/h
Relationship between daily activities and solar availability

Sunlight available

Light Requirements

Praying
Figure ground

Road network

Public realm
Limited access to old Town
Difference is good

BUT

Separation produces dissidence

Need for better integration between old Ksour and New town
Dependencies on routes

Road Network

New function has same route connection typology

Canal rerouted to Ksour
Land of the 1000 Kasbahs
Programme Requirements

Courtyard 440m²
Dressing room 150m²
Warm room 176m²
Hot room 12m² (x9 cubicles)
Bath-master’s room 6m²
Rest room 10m²
Lavatories 1.5m² (x8); 2.1m² (x2)
Boiler room 3000 litre resevoir
Solar collectors 40m²
Frigidariums External Pools

Serve Space: 906.2m²
Serving Space: ?