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Thermal Conditions In Urban Settlements In Hot Arid Regions: The Case Of Ksar Tafilelt, Ghardaia, Algeria

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This research investigates the influence of natural ventilation on the indoor thermal environment in the residential vernacular architecture of Ghardaia. The research was performed through a field study investigation during the hot summer period. The investigation included similar natural ventilation strategies, i.e. daytime, full-day and night-time ventilation. Two settlements, one historic and traditional and one contemporary but described as an "eco-city", have been examined using field measurements and computer modelling. field air temperature and the relative humidity were measured using data loggers were the primary measurements taken in the field, comparing street's air temperature it was found the in Tafilalet was 4k higher than beni Isguen, over one week and computer modelling of the settlements was conducted using VI-Suite software. The main part of the paper assesses the indoor comfort trends and implications of urban form, with a particular reference to the effect of varying density and presents strategic findings. It calls for continued research and development, particularly in the field of modelling the urban microclimate as a function of design. The results show that natural night ventilation in the traditional settlement is the most effective strategy for passive cooling in vernacular dwellings during the hot summer period.

KEYWORDS: Energy, Comfort, Urban form, Air temperature

1. INTRODUCTION

In an urban context, the main objective of environmental design is the creation of urban areas offering comfortable outdoor spaces. However, unlike the interior spaces of buildings, defined by relatively regular and controllable thermal conditions, exterior urban spaces are characterized by large daily and seasonal variations in microclimatic parameters, which are much more difficult to control (air temperature, wind and radiation for example). The specificities of the urban environment generate noticeable climatic changes at all levels. Therefore, understanding the relationships between urban morphology and the physical parameters of the local microclimate are essential.

This paper presents two case studies in Ghardaia city in the south of Algeria: **Tafilelt** and **Beni Isguen**. They were selected as they have two different patterns of neighborhoods, in a microclimate of about 1.5 km^2 (Figure 1). Comparisons are based on the urban thermal performance, to reveal how differences in urban patterns of land use and population densities affect the outdoor climate conditions and in turn pedestrian comfort and indeed indoor conditions. Subsequently, this will give real lessons and significant ideas on how the application of sustainable design maintains outdoor and indoor comfort. The choice of Ghardaia in this research is for the purpose of studying the improvement of outdoor thermal behavior based on thermal simulation and sensitivity analysis with peak outdoor temperatures as the criteria. The findings in this study are pertinent to a building's ventilation strategy integrated into the building envelope design and optimization.

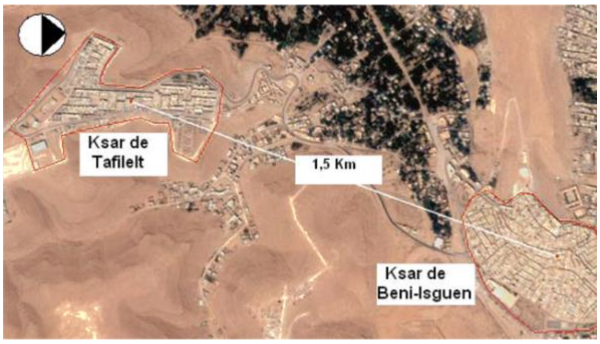


Figure 1: overview of the two settlements

2. METHODOLOGY

This study examines specific considerations of street orientation. The two case studies represent two types of architecture: the vernacular (Beni Isguen) and modern (Tafilelt) in Ghardaia City. The adopted steps are outlined in three simultaneous approaches being followed:

2.1 Site parameters

in order to simulate the urban canyons (Figure 1), site surveys were carried out in both locations. In particular measurements were made to determine the aspect ratio Height/Width, for both canyons which had similar orientations (NW-SE).

2.2 Model the radiation environment

The two settlements were modelled using ArchiCAD and applying it within VI-Suite Software, to study the simplified synthetic urban fabric of both settlements. This aims to provide an approach to quantifying the urban form design element and adapting the master plan for the present and future times. This is based on the thermal pedestrian comfort which shows the effect of the compactness of the settlements and the depth of the streets on solar gain received. The geometry of the two points A and B in the different settlements was input to ArchiCAD and uploaded to Vi-Suite to perform shadow mapping analysis. In this context shadow mapping is the prediction of how often points in space are in direct sunlight when the sun is above the horizon. Simulations in the VI-Suite were done for the summertime using mesh geometry within the scene as the calculation points, with four calculations per hour, using the urban building geometry as the calculation points.

2.3 Field monitoring

Conduct monitoring of the air temperature and relative humidity in the streets. HOBO data loggers were used to measure and record outdoor 15-minute climate data for one week during the summer: from 03/08/2018 to 09/08/2018. The monitoring targeted two points outdoors (two measurement stations) and two points in living rooms in both settlements. External measurements were made by placing each logger within a white (open beehive type) solar radiation shield, suspending this in the middle of each street at 2m height, and away from any heat source or another form of interference. Measurements were taken during representative days of summer conditions. This work presents the analysis only of the data corresponding to one week, in relatively low wind conditions. The data from these two stations characterize the local climatic effect of the streets, and this has been compared with the meteorological data from the airport, 2km away.

3. URBAN FORM OF THE CASE STUDIES

Ghardaia is located in the centre of the northern part of the Algerian desert. It is situated 600 km south of the capital Algiers at latitude 32° North and longitude 2°30’ East. The climate of the Ghardaia city is a hot desert climate characterised by summers with torrid heats reaching 50°C and soft winters with the average minimum just above freezing point. The relative humidity is very low except for the winter months where 60% is common [1].

The valley of the “wadi” M’Zab " Ghardaia” includes five "Ksour" (small strengthened cities), founded over more than six and a half centuries (1011 until 1679) [2]. During all this period the knowledge of the local people adapted to the environment and construction knowledge was undoubtedly refined to contribute to improving comfort in the local (thermally) very demanding conditions. The M’Zab Valley is situated in the south-east of Algeria, in the full desert and belongs to a hot dry climatic zone. Renowned for its secular architecture and remarkable integration of the urban forms to the whole conditions of the natural environment [3], it has today undergone extensive changes which have affected these exceptional characteristics.

Figure 2: View of Ksar Beni Isguen

Figure 3: View of Ksar Tafilelt

The organization of each city consists of three great layers: the ksar is generally established in the core of the settlement which is built overall out of traditional materials, the habitat of the palm grove at the edges with a variation of the building density, generally very far from the Ksar, and contemporary extensions with rather high densities and a horizontal spreading out. They are generally made out of traditional materials with little vegetation [4].

3.1 Beni Isguen

Located in the M’Zab Valley, Beni-Isguen city is one of its five strengthened cities. It is composed of juxtaposed morphological areas which have relatively clear limits and marked differences. Compact urban forms characterize the old city centres, especially in the Saharan cities. These centres are often very dense and appear as a large concentration of buildings in a dense urban radius. Depending on their morphology, there are: the traditional island, e.g. "Beni Isguen" with its irregular street network, and the Haussmannian island with a regular street network, e.g. Tafilelt. See Figures 2 and 3.

3.2 Tafilelt: Algeria's first eco-friendly desert city

Tafilelt is an “eco-city” in the Sahara and a 20-year project to make the desert bloom with all residents helping to plant trees and recycle waste. The ksar of Tafilelt, initiated in 1998 by the Amidoul foundation as part of a social project, is set on a rocky hill overlooking the ksar of Beni-Isguen. This urban complex, with 870 housing units, has plots, streets, alleys, walkways, playgrounds and accompanying structures, such as library, school, shops, community house [5], gym and leisure facilities (park). Considered to be the extension of the old Ksar of Beni-Isguen, this new ksar was built thanks to a financial arrangement involving: the beneficiary, the State (in the framework of the formula '' Participative Social Housing '') and the community through the **Amidoul** foundation. See Figure 4. To ensure thermal comfort, some traditional architectural and urban principles have been updated.

Figure 4: View of the edge of Ksar Tafilelt

4. RESULTS

4.1 The influence of compact shapes on outdoor conditions “A”

A compact urban fabric is generally narrow and deep in Beni Isguen. See Figure 2. It prevents the sun's rays from reaching public spaces (streets, squares or interior courtyards) and generates shadows which contribute to increasing the comfort of these spaces. conversely, in stable weather and in hot periods, these spaces favour the phenomenon of radiative trapping, thereby increasing the surface and air temperatures and the risk of discomfort. This radiative trapping is due to the multiple reflections of the solar rays by urban surfaces.

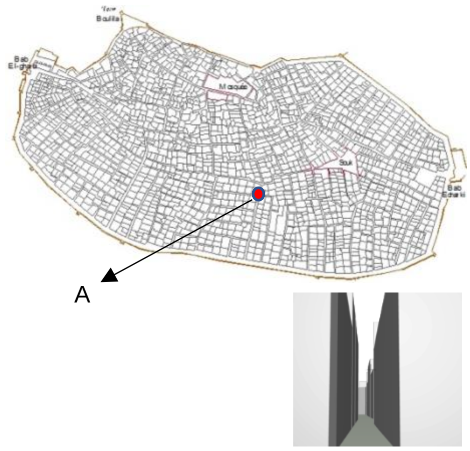


Figure 5: The location of house” A” in Beni Izguen

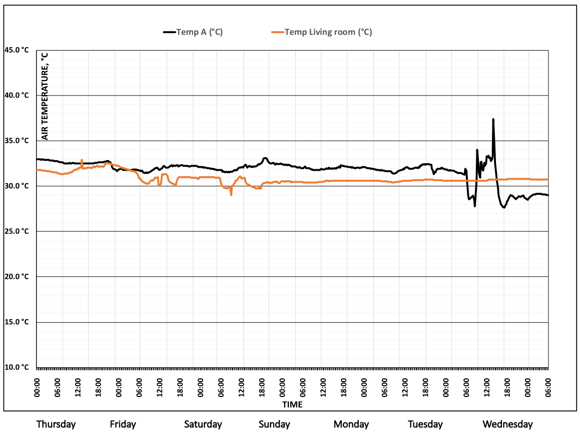


Figure 6: Comparison of the air temperature outdoors and a living room in location “A” for one week

4. 3 The influence of regular urban shapes on outdoor conditions “B”

In the case of Tafilelt (Figure 7), the streets are 80% wider compared to location A (Beni Isguen) by about 1,5 metres which in turn makes them more exposed to the sunlight (Figure 5).

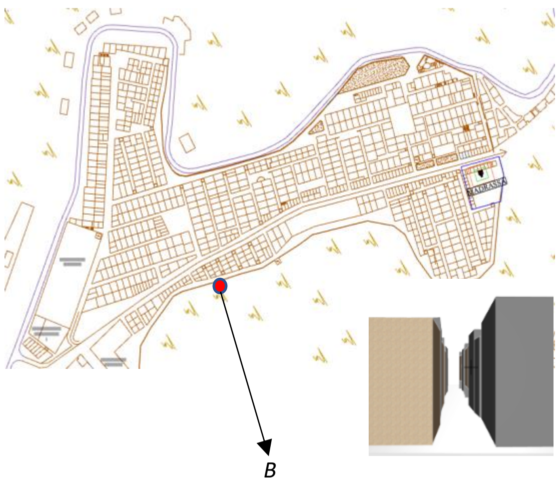


Figure 7: The location of house “B” in Tafilelt

In addition, an increase in temperature inside the buildings (Figure 8) was also observed which then has an impact on thermal comfort of their occupants.

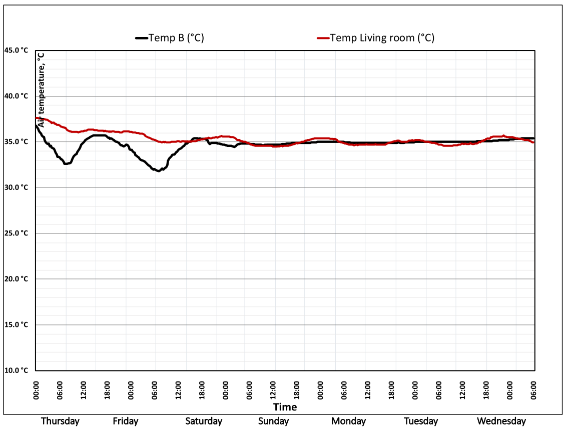
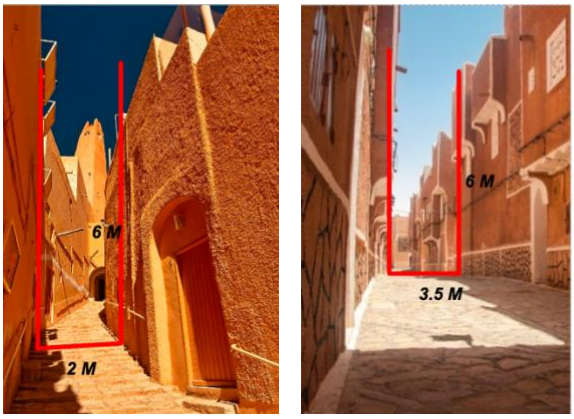


Figure 8: Comparison of the air temperature for outdoors and a living room in location B for one week

The orientation of urban fabric is a spatial parameter used to analyse the accessibility of solar energy and daylight within street gorges. It creates shaded and sunny surfaces leading to variations in ambient and surface temperatures



A: H/W=3 *B: H/W=1.7*

Figure 9: The width of the road at both sites

Morphologically, this indicator produces forms of sun protection or exposure in urban spaces.

The protection is often effective, only at the start and end of the day, depending on the orientation of the building. Indeed, when the sun is at its zenith, the shaded areas are very reduced (Figure 10).

5. DISCUSSION

The results' analysis shows that location A has deep streets in dense urban tissue which act as heat traps. Solar protection, from the narrow street gorges (H/W =3) are very important in the thermal behaviour in the summer. Because of the reduced solar access, use of light brown colours, and the weak anthropogenic heat generation; air temperature decreases of 8°C were recorded in summer compared to the meteorological airport data. Given the shading effects in "B", the temperatures outdoors are very different from those of "A". The average weekly temperature of "B" remains fairly similar to the meteorological airport data. The average temperatures of the two locations obtained during the week of the study were compared. This comparison shows that during the day the greatest difference between the two places amounts to 8°C on Sunday at 15:00. The H/W ratio of Tafilelt allows more solar radiation into the street gorge and moreover the upper part of the west façade receives the sun for longer (Figure 10).

Figure 10: The shading in both streets, each oriented south-west, at 3:00 pm

In a very similar way, the average temperature of the southwest façade remains slightly higher than that of the northeast façade (Figure 10). However, during the night the temperatures of the streets are lower than those of the other elements and that of the air probably because of the radiative deficit. On the one hand, the roofs have a wide view of the sky and in addition, they are highly exposed to the wind, thus returning more heat to the sky in infrared and by convection. During the cloudy days, the temperature of the surfaces is controlled more by the atmospheric infrared flux and the incident diffuse flux.

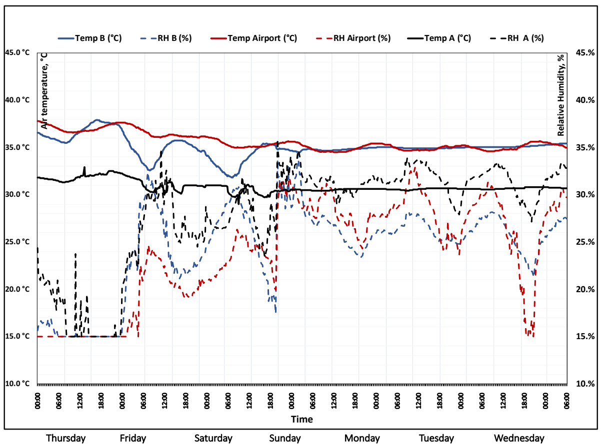


Figure 11: Comparing the outdoor temperature and humidity for both cases with meteorological airport data for one week

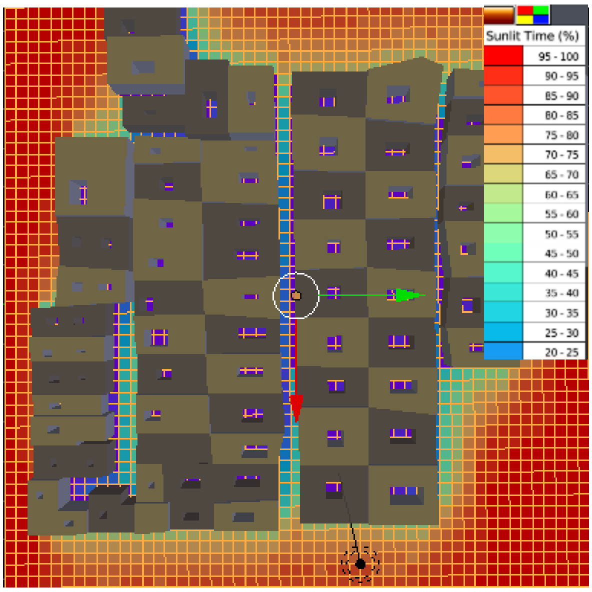


Figure 12: Shadow mapping for Beni Isguen

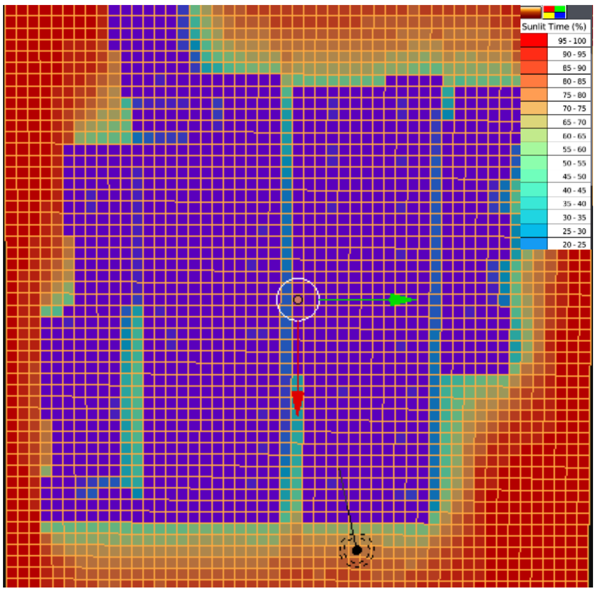


Figure 13: Shadow mapping with building removed for clarity, Beni Isguen

Streets in “A” are less exposed to the sun because of the height to width ratio of the narrow streets [9]. The roofs, characterized by a high sky view factor, still have the highest temperatures during the day. They thus play a major role in the absorption and return of solar energy especially in location "B".

In order to study microclimate for urban planning land use, the Compactness Degree for the built-up area was used as a parameter to measure the surface exposure to the sun. in both places, the same surface area and the same orientation were selected.

Based on shadow mapping in both places it was observed in case A (Figure 12, 13) that the ratio of the surface exposed to the sun to the surface in shadow was lower compared to case B (Figure 14, 15).

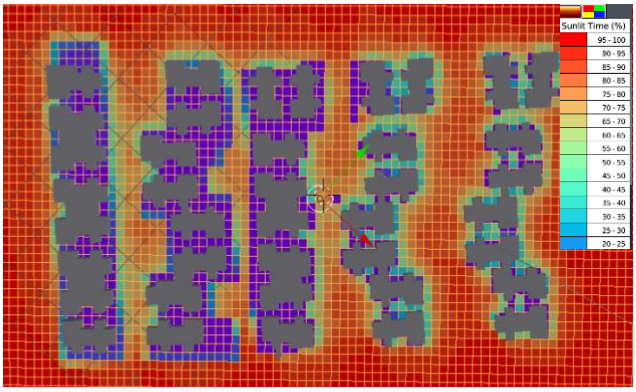


Figure 14: Shadow mapping for Tafilelt

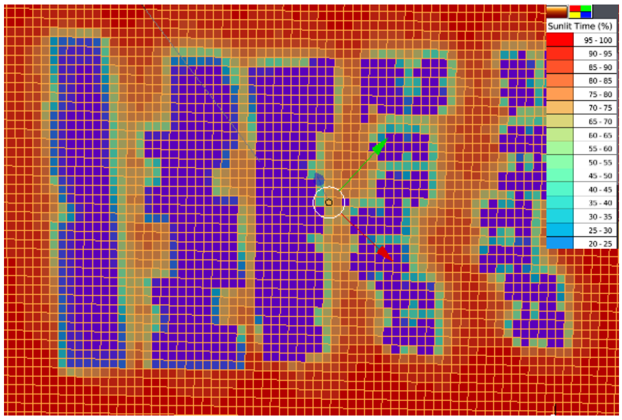


Figure 15: Shadow mapping with building removed for clarity, Tafilelt

The duration of sunshine indicates the sum of the time intervals during the day that buildings and streets are subjected to insolation during a given period. The duration of sunshine in a district can affect the average radiant temperature, a physical component of thermal comfort that integrates the flows of short and long wavelengths. The longer the duration of sunshine, the higher the amount of incident solar energy, which can increase the risk of discomfort. Figure 12 shows the results of the simulation of the duration of sunshine for one day, Wednesday. Location B in Tafilelt settlement is the one that receives the most solar radiation with 47.0% of the time, i.e. more than 6h35 min. In contrast, location "A" in Beni Isguen receives solar radiation for 32.2% of the time, i.e. 4h20 min. See Figures: 12,13,14,15. The shortest duration of sunshine is obtained for Beni Isguen, with only 4 hours of sunshine. This short duration is mainly due to the compactness of the urban tissue and the narrow width of the streets.

5. CONCLUSIONS

Two settlements, one historic and traditional and one contemporary but described as an “eco-city”, have been examined using field measurements and computer modelling. In the context of a very dry and very hot climate the role of buildings and their placement, i.e. the resulting urban morphology, must be to reduce the temperature and promote greater comfort in a passive way as far as is possible.

Tafilelt, although built using traditional materials, departs from the historic urban form found in Beni Isguen. The buildings were found to be more widely spaced, with streets almost 100% wider (3.5m rather than 2m). Building heights are similar, and this leads to a 50% reduction at Tafilelt of the H/W ratio. Street level solar exposure is thus much greater at Tafilelt – some 50% more than at Beni Isguen.

The impact of this on the air temperature experienced by pedestrians (and on the air entering buildings) was revealed by the air temperatures measured in the two streets. Over four days the air temperatures in the Tafilelt street were very similar to that of the airport's met station temperatures, and both locations were some 4-5K higher than in the Beni Isguen street. The traditional morphology of the latter clearly provides a major benefit in terms of comfort and reducing the need mechanical cooling.

Given that Tafilelt was designed as an eco-city, it is surprising to find, albeit based on the evidence of short-term monitoring, that it results in higher urban temperatures. Whilst the choice of materials for the town (very traditional) and its emphasis on planting of vegetation must be commended, allowing much greater solar radiation to enter the urban structure is unhelpful. The width streets give access for the vehicle to access houses, clearly width streets allow better access for vehicles but that's comes as its cost highest urban temperature. It would be worth investigating options to counter this effect, e.g. street shading, more reflective materials, etc. This is the subject of ongoing research.

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