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## STREET CANYON MICROCLIMATE IN TRADITIONAL AND MODERN NEIGHBOURHOODS IN A HOT DRY CLIMATE – A CASE STUDY IN FEZ, MOROCCO

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**ABSTRACT:** The urban climate can vary considerably within cities. In a hot and dry climate, the micro-climate at street level depends to a large extent on the urban geometry and building density. To be able to plan and design comfortable urban areas in the future, it is important to understand how different urban textures influence the climate. This paper deals with a case study in Fez, Morocco, where climate measurements took place in two entirely different types of neighbourhoods: a modern, suburban area with wide streets and many open spaces and a traditional, dense neighbourhood in the old city. The results show significant differences between the two neighbourhoods. In both summer and winter the minimum temperature was 2–4°C lower in the modern area, and the maximum temperature was about 10°C higher. In summer the modern area was extremely uncomfortable whereas the traditional was within the comfort zone. In winter neither area achieved comfort, but the modern was better.

Conference Topic: 2.7 Case Studies

### 1. INTRODUCTION

It is well known that the built environment modifies the climate [1]. The best known phenomenon is the heat island, which is mainly characterized by higher nocturnal temperatures in the city than in the surrounding countryside. Since buildings obstruct air movements, urban areas have lower wind speeds but increased turbulence. It has been found that the geometry of buildings and properties of building materials have a strong influence on the urban climate [1]. Urban parameters such as building density, height to width ratio of street canyons, thermal admittance and colour have a direct influence on the climate around buildings. This modified climate affects the comfort of humans at street level. It also influences the thermal stress on buildings and thus affects indoor comfort as well as energy use for heating and cooling.

It is possible to create a good urban climate through conscious urban planning and design. However, in most cases the climate is not sufficiently considered in the planning and design processes and, as a consequence, many urban areas are uncomfortable. Whereas comfort and energy use within single buildings have been studied extensively, outdoor comfort and energy use in urban areas have had little attention. The reason is often due to lack of knowledge among professionals and decision makers. Another factor often noted by architects and planners is the lack of easy-to-use tools [2]. Climatic aspects are seldom considered in urban planning codes. The problem is especially great in developing countries with rapid urbanization, where cities grow with little control. Today's urban design is often inspired by western movements and trends developed for a totally different climate. In developing countries, urban codes, often a heritage from the colonial period, constitute another constraint for climate-conscious design.

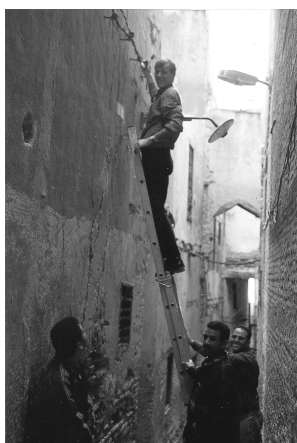
As a part of a current cooperation project between the Department of Housing Development & Management at Lund University, Sweden, and the National Laboratory for Tests and Studies (LPEE), Morocco, the urban climate in Fez was studied. The objective of the project, which is funded by the Swedish International Development Cooperation Agency (Sida), is to examine how different types of urban textures influence the urban climate in a hot dry climate. It is hoped that the project will result in recommendations for urban design in a hot dry climate. The implementation of such guidelines could lead to increased comfort and lower energy use in urban areas.

In a preliminary study in 1998, momentaneous measurements indicated large differences in air temperature between a modern, sparsely built-up area and a traditional, dense area. Both areas had nocturnal heat islands, but the modern area was as warm – or warmer – than the official climate of the airport (rural area), while the traditional area was cooler by day [3]. The results presented here are from a second, longer measurement period during the winter and summer of 2000.

### 2. METHOD

#### 2.1 The Streets Studied

Two street canyons were studied in two different areas of Fez (34°N). The streets were chosen to represent two extremes: one modern residential neighbourhood (the Adarissa District) and one traditional residential neighbourhood (the Seffarine District in the Medina).



**Figure 1:** The modern (above) and traditional (below) streets where the measurements were taken.

The modern neighbourhood, a suburban area at the southern outskirts of the city, is characterized by wide streets – designed for vehicle traffic – and several open squares and large street intersections. The buildings along the streets are semi-detached and 3–4 stories high. There are 1.5 m high walls at the boundary between the street and the plots. Trees are planted on the pavement outside the walls. The shallow street canyon has a height to width (H/W) ratio of about 0.6, and a sky view factor (SVF) of 0.64 in the middle of the street. (Fig. 1)

Seffarine, the traditional neighbourhood, is one of the oldest and densest districts in the Medina of Fez.

The chosen street canyon is only 1.4 m wide and surrounded by 4 storey buildings. The H/W ratio is about 10 and the SVF only 0.05. (Fig. 1)

Both streets are oriented approximately East-West. The traditional street has a H/W ratio 17 times that of the modern street.

In the modern area, the 250 mm thick walls consist of plastered hollow blocks. The houses have relatively large windows. Each building has a small garden in front and a somewhat bigger behind. The façades are white or light beige. In the traditional area the walls consist of up to 1 metre thick masonry of dense burnt clay bricks, so the façades are darker. The buildings have almost no openings towards the street, but all rooms open towards the courtyard.

## 2.2 Measurements

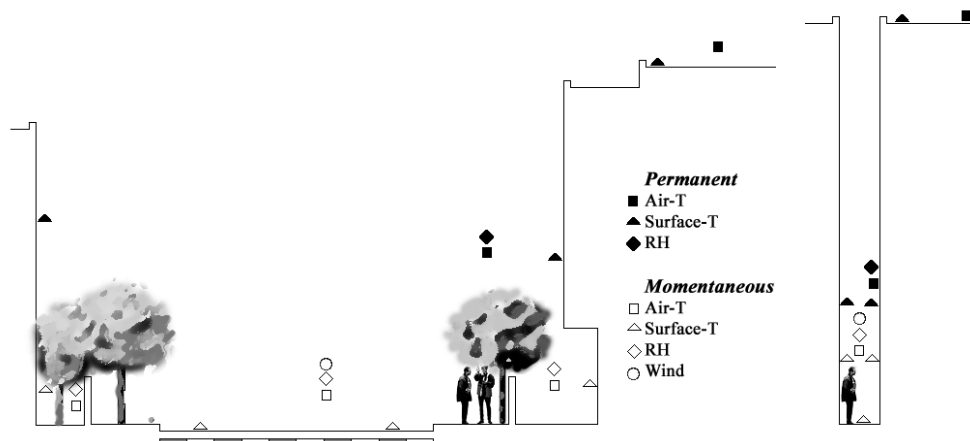
Measurement probes were mounted at different points in the streets to measure the climate continuously during both summer and winter (Fig. 2). Air temperatures were measured at street level and at roof level in each street. The surface temperatures were measured within the canyon – on both façades – and on one of the roofs. The relative humidity (RH) was measured at street level.

In addition to the continuous measurements, momentaneous measurements were done in each street three times per day (early morning, early afternoon and evening) during one summer and one winter week (Fig. 2). These measurements included air temperature and RH in the street canyon, surface temperatures of the façades and the street, and horizontal and vertical wind speed. In the wide street in the modern area, air temperatures and wind speeds were also measured along each façade.

## 2.3 Simulation of Urban Climate

Attempts to simulate street temperatures were done with the Cluster Thermal Time Constant (CTTC) model [4]. This is a fairly simple model for calculating air temperatures in urban canyons. The model considers SVF and urban density. In this model the air temperature in the street canyon is heated by the ground, which in turn is heated by direct solar radiation and cooled through net outgoing longwave radiation.

**Figure 2:** Measuring points for the permanent equipment and momentaneous measurements in the modern (left) and traditional (right) street canyon.



### 3. RESULTS

Although similar at roof level, the climates at street level differ significantly between the modern and traditional neighbourhoods. This is in agreement with previous measurements [3].

#### 3.1 Air Temperatures

The air temperatures differ considerably between the two neighbourhoods. The difference between the areas is similar in both winter and summer. During the coldest part of the day – the hours before sunrise – the traditional street is 2–4°C warmer and during the warmest part of the day – in the early afternoon – around 10°C cooler. These figures apply to days with clear or nearly clear skies. Figs 3 and 4 illustrate a typical winter and summer day respectively. The diurnal amplitude was about 20°C in the modern area on both days and about 6°C in the traditional area.

In the modern area the air temperatures at roof level and within the canyon were similar. The air temperature close to the façades differed up to a few °C from the temperature in the middle of the street. In the night and early morning, the air was warmer close to the façade and in the afternoon it was cooler.

#### 3.2 Surface Temperatures

In the modern area surface temperatures of the façades varied with height. The façade at the northern side of the street (facing south) receives solar radiation and consequently becomes warmer than the southern façade. However, its temperature seldom exceeded the air temperature in the canyon. The permanent probes at 5–6 m height registered larger diurnal swings than those at lower level (1.5 m). The warmest surface in the canyon was the northern part of the street, where the temperature reached about 25°C in the winter and 50°C in the summer week. The highest temperature was registered at the surface of the roof (over 55°C in the summer).

In the traditional area the surface temperatures differed only slightly from the air temperatures and were practically identical on both façades and at both heights (1.5 and 3 m). The street in the traditional area was 0.5–1°C cooler than the walls during the both winter and summer. The roof had by far the highest surface temperature, very similar to that in the modern area.

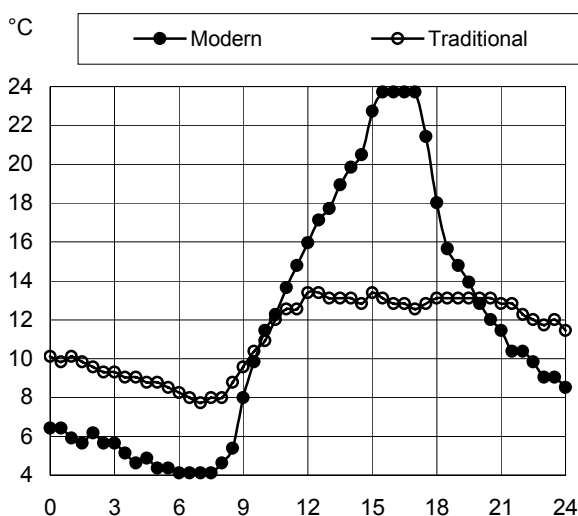
#### 3.3 Humidity and Wind Speeds

The absolute humidity is slightly lower in the modern area, both in summer and winter. The relative humidity varies greatly in the modern area but is very stable in the traditional area (Table I).

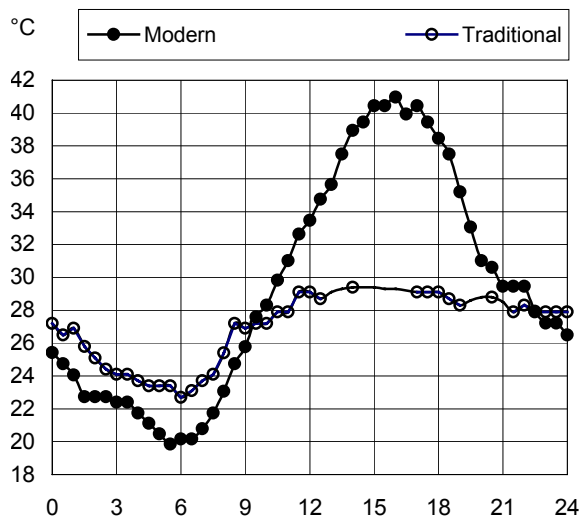
**Table I:** Absolute and relative humidity in the modern and traditional area on 10 February and 29 June 2000.

	Winter		Summer	
	Modern	Trad.	Modern	Trad.
ave. abs. hum. (g/m <sup>3</sup> )	5.8	6.9	9.1	10.8
min RH (%)	20	55	11	33
max RH (%)	95	77	65	53

The measured wind speed varied greatly from day to day and according to the time of day. As expected, wind speeds were lower and less turbulent in the traditional area. The modern area had an average wind speed of 0.8 m/s in the winter week and 0.7 m/s in the summer week. In the denser traditional area, the average wind speed was about 0.4 m/s in both winter and summer.



**Figure 3:** Air temperatures in the two neighbourhoods on a typical winter day (10 February 2000).



**Figure 4:** Air temperatures in the two neighbourhoods on a typical summer day (29 June 2000).

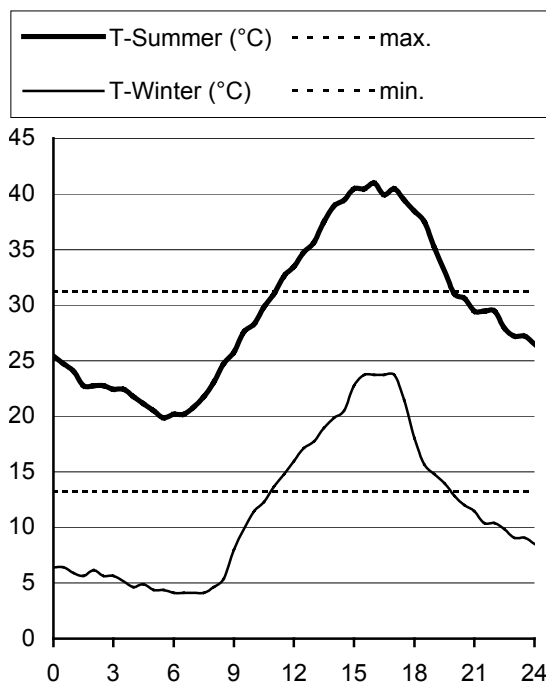
### 3.4 Outdoor Thermal Comfort

Knowing wind speed and humidity it was possible to define the upper and lower temperature limits for thermal comfort in the two neighbourhoods. The comfort zones (Figs 5 and 6) are based on average values of wind speed and humidity for each day. The activity level was assumed to be 1.3 met (135 W) which represents slow walking. The upper and lower limits of comfort were determined assuming a clothing value for summer of 0.6 clo (light summer clothing) and an insulation value of the winter clothing to 1.6 clo.

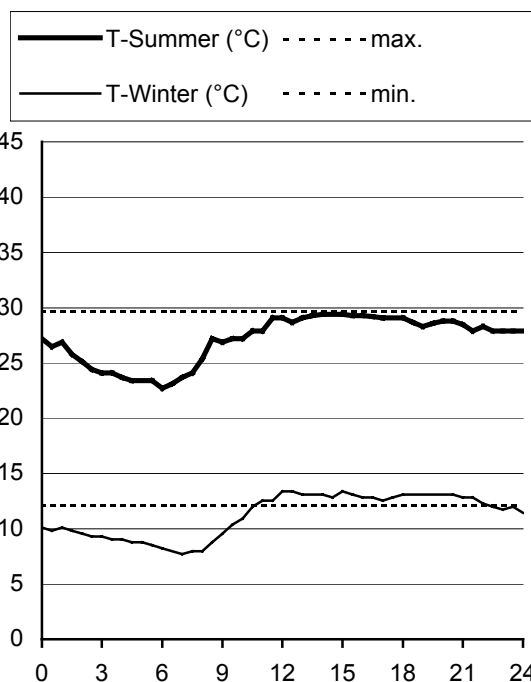
Note that the mean radiant temperature was assumed to be equal to the air temperature, which means that neither the received solar radiation nor the exchange of longwave radiation between a human being and objects in the urban environment, such as walls, street and the sky vault, are considered. In the traditional area the error is probably small because the SVF is very small and the surface temperatures of the walls and street are almost equal to the air temperature. However, in the modern area longwave radiation from the street and to the sky as well as solar radiation will influence thermal comfort [5].

### 3.5 Simulation of Urban Temperatures

The CTTC model, which was successfully used in similar climates [4], gave reasonable values for the modern area in the summer. However, for the traditional area and the modern area in winter, the model estimated too low air temperatures.



**Figure 5:** Air temperature variations in the modern area on a typical winter and summer day. The upper limit for summer comfort and the lower limit for winter comfort are shown.



**Figure 6:** Air temperature variations in the traditional area on a typical winter and summer day. The upper limit for summer comfort and the lower limit for winter comfort are shown.

## 4. CONCLUSIONS

### 4.1 Explanation of the Temperature Differences

The difference in temperature between the sparsely built-up modern area and the dense Medina is remarkably large. Especially interesting is the difference of about 10°C during the warmest part of the day in both winter and summer. The differences are believed to be a combination of several factors, all of which are related to the urban geometry. These factors include:

- Solar access
- Outgoing longwave radiation
- Thermal storage
- Wind shelter

Other factors such as heat from traffic, space heating and cooling, and industrial activities are not believed to have a significant impact in the studied areas.

The large difference in H/W ratio (and SVF) between the neighbourhoods means that the streets in the modern area receive much more direct and diffuse solar radiation, but also that they have a considerably larger net outgoing longwave radiation towards the sky. This explains why the modern canyon heats up more during the day and cools down more during the night.

The stable climate in the traditional canyon is partly attributed to the large mass of the Medina. The ratio between the total surface of walls and street and the air volume in the canyon is considerably higher in the Medina. The traditional building materials (dense bricks) also have greater heat

capacity than the modern ones (hollow blocks), so a larger part of the increased air temperature during daytime will be absorbed by the canyon surfaces and released during the night, which reduces diurnal swings. Due to its high thermal inertia, the Medina also withstands sudden climatic changes better than the modern area.

The higher building density in the Medina results in lower wind speeds. Thus, there is much less mixing of air horizontally and vertically than in the modern neighbourhood, which helps maintain temperature differences between the canyon and the air layer above the rooftops.

In the shallow modern canyon temperatures differ only slightly from the temperatures at roof level. This agrees with a more extensive study of a canyon of  $H/W \approx 1$  in Kyoto (35°N) [6]. However, a microclimate is developed in the area between the wall/trees and the façade (see Fig. 2). This is the reason for the more conservative climate in this area. The trees shade the wall and the ground during the day – resulting in lower surface temperatures – and the wall/trees hinder outgoing longwave radiation to the sky.

In the traditional Medina there is a great difference between the street climate and the roof level climate. During the night the warmer, lighter air in the canyon will rise and be replaced by cool, heavy air sinking from the roofs forming a 'cool pond' at street level. In the daytime there are no forces to stimulate such air exchange since the cooler air lies under the warmer air.

#### 4.2 Thermal Comfort

Figs 5 and 6 show that in the summer, the traditional street has a much more comfortable climate than the modern street. In fact, for the studied day the climate of the traditional area is entirely within the comfort zone. In the modern area, the temperatures exceed the comfort zone all afternoon, and the maximum temperature is about 9°C above the upper comfort limit. It should be noted that the temperatures shown in Figs. 5 and 6 are in the shade. In the modern street it is actually difficult to find shade during a sunny summer day due to the high elevation of the sun.

In the winter both streets are within the comfort zone only in the afternoon. However, considering the possibility of solar access, winter comfort in the modern area is better than shown in Fig. 5.

Seen over the whole year the traditional area has a favourable summer climate whereas the modern area – which receives some direct solar radiation – is better in the winter. To achieve comfort in the summer, future urban areas should be denser than at present. However, it is not realistic to construct areas as dense as in the traditional Medina. The extremely narrow streets are not practical for modern lifestyles. Furthermore, it is not advisable from a climatic point of view, since the winter climate is poor. From a climatic point of view urban areas in this climate should be denser than at present; some streets could be quite narrow, but there must be streets for vehicle access, and there must be urban spaces with solar access to allow for winter comfort.

#### 4.3 Simulation of Urban Climate

A possible reason the CTTC method gave poor results for the winter season is that the street does not receive direct solar radiation. The same thing occurs with the traditional street because of its large  $H/W$  ratio.

### 5. FUTURE STUDIES

Further attempts will be made to simulate the urban climate. Improved versions of the CTTC model [e.g. 7] and other available programmes will be tested. The objective is to find easy-to-use tools to predict the effect of different urban designs on outdoor comfort. The comfort aspect will also be studied more thoroughly by taking into account short and longwave radiation.

Based on the measurements presented in this paper, and coming simulations, guidelines will be proposed for urban design in hot dry climates. It is hoped that such guidelines be integrated in existing planning and building codes to increase the likelihood of better comfort in new urban areas.

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