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Abstract

The proportion of the world's population living in urban areas is constantly increasing. Different urban shapes result in different microclimates. The way cities are planned and built is therefore important for the global energy use. This study presents results from measurements of street climate in the city of Fez, Morocco, in contrasting traditional and modern housing areas, each with its own problems and qualities. Air temperature, relative humidity and wind velocity were measured in the two types of housing area, during both hot and cold seasons. These preliminary results confirm the night-time heat island phenomenon, while during the day the two areas show different behaviour. Further studies aim at recommendations on how to plan and build new housing areas in the region, to increase urban and indoor thermal comfort.

INTRODUCTION

The proportion of the world's population that lives in urban areas is constantly increasing. Urbanisation gives rise to economic growth, which results in higher energy use for e g cooling and heating buildings. The way cities are planned and built is therefore important for the global energy use.

As part of a cooperation project between LPEE in Casablanca and HDM in Lund the effect of urban climate on buildings in hot and dry areas is studied. The project is sponsored by Sida – Swedish International Development Cooperation Agency.

Background

Fez, with almost one million inhabitants, is the fourth largest city in Morocco. Fez is situated 33°58'N 04°59'W, at 571 m above sea level in a valley between the Atlas Mountains in the South and the Rif mountains in the North.

The climate of Fez is characterised by hot and dry summers and cold winters with rare snow. Annual mean temperature is 17°C and rainfall is 540 mm. Monthly climate data is shown in Figure 1.

Fez consists of two contrasting parts: the traditional Arabic-Islamic, medieval city centre, the *Medina*, and the modern city with its roots in the French colonisation, la *Nouvelle Ville*. One housing district in each part of the city was studied.

Seffarine in the Medina is one of the most densely developed areas. Introverted courtyard buildings in two to four stories surround the narrow streets, which cut deep ravines through the city. The street network is irregular, which means that the buildings shade each other. There is a great variation of traditional building elements and a large number of building details provide shade at street level.

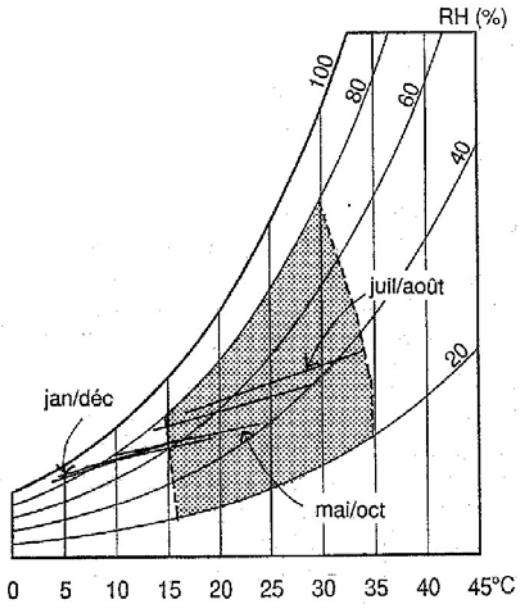

Figure 1: Monthly temperature and humidity variations in the climate of Fez. The comfort zone (grey) is for a wind speed of 2 m/s, and an activity level of 1.3 met. The lower limit is for 1.6 clo and the higher limit for 0.6 clo (winter and summer clothing respectively).

Adarissa is a modern, two to three storey housing area in the new part of Fez, planned and built as a suburb with extroverted linked houses. The area has a regular pattern of wide streets planned for car ownership. This low density means both buildings and the ground are exposed to a great amount of solar radiation. Only a few trees provide shade for some facades and footways.

Figure 2: Street environment. Left: Seffarine in the old city. Right: Adarissa, a modern housing area.

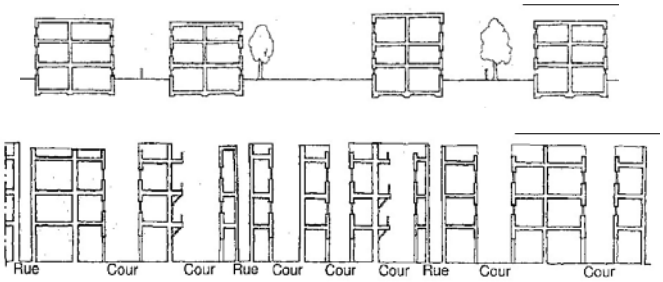

Figure 3: Street sections. Top: Adarissa, the modern area. Bottom: Seffarine, the traditional area.

In both neighbourhoods buildings and streets are made of heavy building materials. The Seffarine houses are made of thick walls of solid clay bricks and the streets are paved with concrete stones. The Adarissa houses are made of stone walls (basement) and hollow bricks, and the streets are made of asphalt.

Problem

Different urban shapes result in different urban micro-climates. This study seeks to define relevant parameters in traditional and modern living areas. The aim is to find combinations of qualities from both environments, to be used in guidelines for future housing development in Morocco.

METHOD

Measuring Points

In each neighbourhood five measuring points were studied. Measurements were made in different types of streets – main street, local street, alley (cul-de-sac), and open and covered streets. The streets had different orientations. In Seffarine the height to width (H/W) ratio of the street canyons varied between 1.3 and 8.6, whereas in Adarissa the H/L ratios were 0.5–1.5. In each district an open square was also measured.

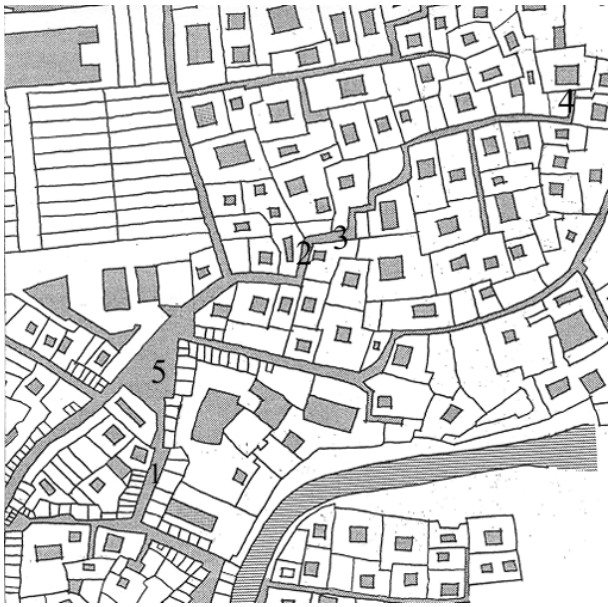

Figure 4: The Seffarine district with measuring points 1–5. The traditional urban tissue contains a variety of different types of streets.

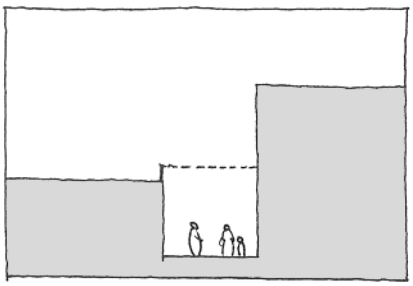

Figure 5: Measuring point 1 is located on the main street, which is 5 m wide. The buildings are 4 and 9 m high respectively.

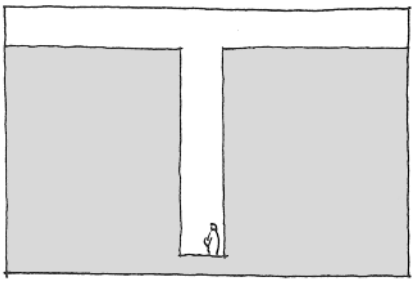

Figure 6: Measuring point 3 is located in a residential street, which is 2.2 m wide. The adjacent courtyard-houses are 12–15 m high.

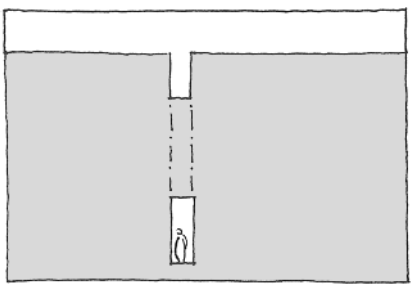

Figure 7: Measuring point 4 is located in an alley, which is partly covered. The street is only 1.4 m wide.

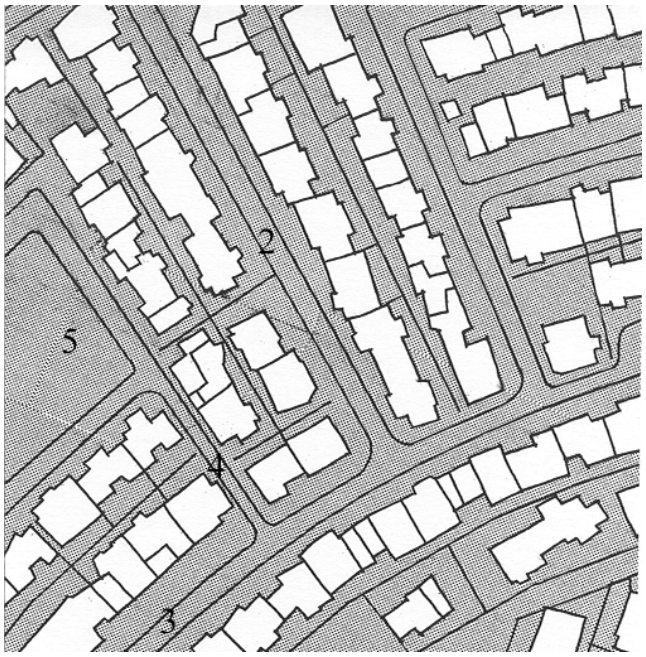

Figure 8: Quartier Adarissa with measuring points 2–5. The modern urban tissue has similar types of streets in the whole housing area.

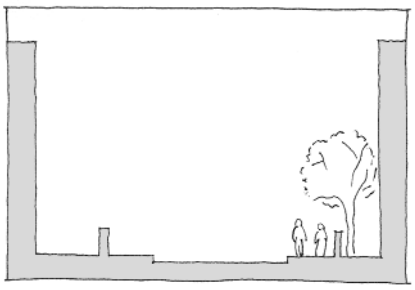

Figure 9: Measuring point 3 is located in a residential street. The distance between the houses is 18 m and the row-houses are 9 m high.

Climate Measurements

The measurements were made during Summer, 17–20 July, and Winter 4–7 December in 1998. The "official" climate for Fez for the actual periods, measured at the airport situated on the outskirts of the city, is shown in Figure 10.

For each measuring point, air temperature, relative humidity and wind velocity were measured in the middle of the street canyon, 2 m above street level. The surface temperature was measured at 1.5 m above street level on each side of the street canyon. See Figure 11. The instruments were protected from sunlight during the measurements. The measurements took place three times per day: at 6 am, 2 pm and 9 pm. The measurements were made in one district at a time: two days in one district followed by two days in the other district.

All measurements were made with the multi purpose instrument Swema Air 300 (manufactured by Swema, Sweden). Different probes can be connected to this instrument to measure air temperature, surface temperature, relative humidity, wind speed, etc.

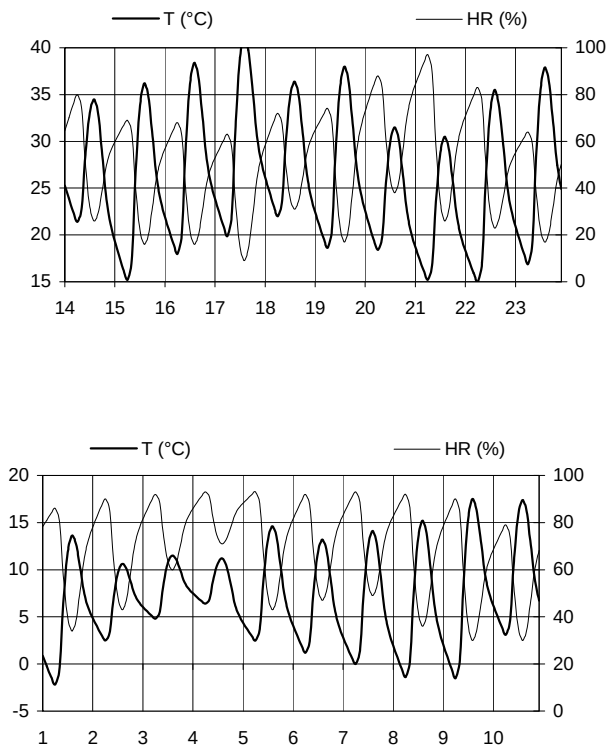

Figure 10: The "official" climate for Fez, measured at the airport situated on the outskirts of the city, for two periods 1998: 14–23 July (top) and 1–10 December (bottom).

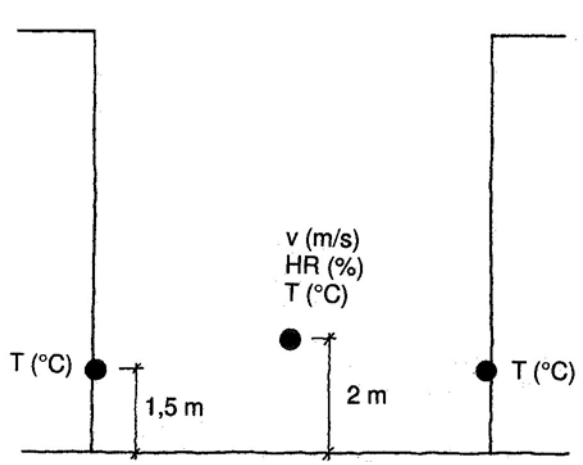

Figure 11: Measuring points in the street canyon.

Air temperature and wind velocity were measured with the Swema SWA 31 telescopic probe. The accuracy of the air temperature is ±0.5°C and wind speed ±3%. Swema Air 300 was programmed to measure the wind speed every second during one minute. The instrument automatically calculates the mean value and the standard deviation. Relative humidity was measured with a Rotronic OP100A, which has an accuracy of ±2%. Surface temperatures were measured with the Swema SWT 28 sensor, which has an accuracy of ±0.5°C.

The measurement probes were calibrated after the measurements and the measured values were corrected.

RESULTS

Figure 10 shows that the summer measurements took place during a climatically stable period and all four days had clear sky conditions. The first day of the winter measurements was cloudy whereas the following days had clear skies.

Air Temperatures

The air temperatures measured in the *Seffarine* district (in the Medina) varied greatly between different types of streets. In summer, the minimum temperatures were 6–7°C higher than the "official" for all measurement points during both days of measuring (19–20 July). In the street canyons with a higher H/W ratio of 1.3 and 0.5 (measurement points 1 and 5), the maximum temperatures were 2–4°C higher than the official temperatures on the first day of measuring (19 July), a warm day, slightly warmer than the previous day. However, in the extremely narrow streets – with a height to width (H/W) ratio of 5 or more – the maximum temperatures were 7–8°C lower than the official ones. The following day, for which the official maximum temperature had dropped by 6°C, the temperatures were very similar to those of the day before, i.e. 0–1°C lower than the official maximum temperature.

In winter, measurements were made on one cloudy day (4th July) and one clear day (5th July). On the cloudy day, the air temperature was constantly 2–3°C higher than the official one, whereas on the clear day the minimum temperatures were 4–5°C higher. The maximum air temperatures for the wider street canyons (H/W ratio of 0.5–1.3) were 2°C higher than the official one, whereas the extremely narrow streets had 1–2°C *lower* temperatures than the official ones.

No significant difference could be observed between streets of different orientation.

Figure 12 shows air temperatures for point 3 in the Seffarine district in summer and winter.

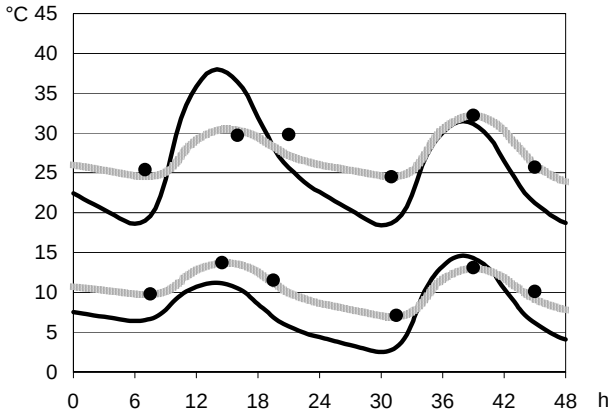

Figure 12: Air temperatures for point 3 in the Seffarine district in summer (19–20 July) and winter (4–5 December). The H/W ratio of street canyon is 5.5. The measured temperatures have been compared with official values from the airport of Fez (thick line).

The air temperatures measured in the district Adarissa varied only slightly from street to street. In summer, the minimum temperatures were 4–5°C higher than the ones measured at the airport. The maximum air temperatures were 0–2°C higher than the official one on 17 July and 3–5°C higher the day after.

In winter, the minimum temperatures were 1–2°C higher than those measured at the airport. The maximum air temperatures were 0–2°C higher than the "official" ones.

As in Seffarine, no significant difference could be observed between streets of different orientation. The small park in the neighborhood had temperatures very similar to those measured in the streets.

Figure 13 shows air temperatures for point 3 in Adarissa in summer and winter.

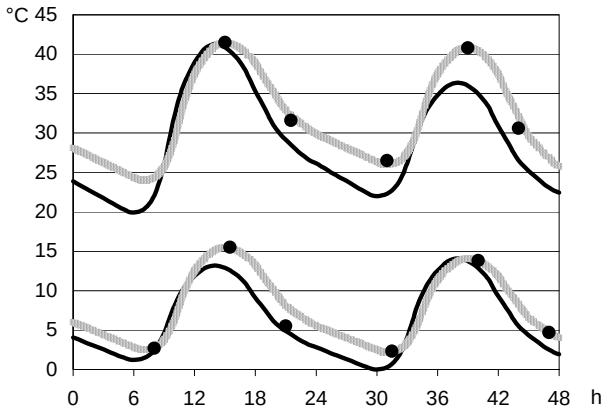

Figure 13: Air temperatures for point 3 in Adarissa in summer (17–18 July) and winter (6–7 December). The H/W ratio of street canyon is 0.5. The measured temperatures have been compared with official values from the airport of Fez (thick line).

Surface Temperatures

In general there were less diurnal fluctuations of the surface temperatures of the façades than for the air temperatures. In the narrow streets of the Medina surface temperatures were very close to the air temperatures and there was no significant difference between façades of different orientations. In Adarissa the surface temperatures could be quite different from the air temperatures, especially during the summer, when surface temperatures often were 3–4°C higher or lower than the air temperature at the time of measurement.

Relative Humidity

The Seffarine district has a higher relative humidity than Adarissa, especially during summer. In July, the measured RH varied between 40 and 50%, being lower during the night and higher during the day than the official one. In winter, the RH was lower during night and higher during day than the official, roughly varying between 60 and 80%.

In Adarissa, the measured relative humidity in the summer was lower than the official one, especially during the night, roughly varying between 10 and 50%. In winter, the RH was lower during the night and higher during day than the official, roughly varying between 45 and 90%.

Wind velocity

The measured wind velocity varied greatly between measurement points and times of measure. The narrow streets of the Seffarine district had an average wind speed of about 0.2–0.3 m/s, whereas in Adarissa the average wind speed was around 0.4–0.6 m/s.

CONCLUSIONS

As only three measurements per day were made during two days per season and district, and as measurements did not take place at the same time in both neighborhoods, the results by no means give a complete picture of the climate. However, the measurements indicate great differences in climate between the extremely dense Medina and the very open urban tissue of Nouvelle Ville.

In both districts the heat island phenomenon is clear with higher night temperatures than reported from the airport outside the city. The effect was a few degrees stronger in the Medina than in Nouvelle Ville. During daytime, however, the two neighborhoods show totally different behaviour. In the densest part of the Medina the air temperature is normally *lower* than the official temperature whereas it is *higher* in Nouvelle Ville. One explanation to this is that the sun does not penetrate down into the narrow street canyons; and most of the sunshine is reflected by the light coloured roofs. Furthermore the dense and heavy structure of the Medina reacts very slowly to temperature differences.

In general, the climatic conditions are much more stable in the Medina than in Nouvelle Ville, regarding both air temperature and relative humidity. Within shorter periods air temperature and relative humidity seem not to respond to changes in the “official” climate.

Too few measurements were made to make any conclusions about the wind velocity, but it is clear that the air movement is less in the Medina than in Nouvelle Ville.

The comfort level is higher in the Medina in summer, whereas the Nouvelle Ville offers an advantage in winter with slightly higher temperatures and more access to sunshine.

In future urban planning climatic aspects should be considered at an early stage. Effort should be put on developing adequate tools to simulate the impact of different urban tissues on the urban climate.

Continuous measurements are needed to obtain a deeper understanding. Such measurements will be carried out within the project during 2000.

REFERENCES

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