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Modeling the urban geometry influence on outdoor thermal comfort in the case of Moroccan microclimate

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ABSTRACT

Thermal indoor conditions depend not only on the building envelope but also on the thermal outdoor conditions. It is therefore important that a great interest should be paid to outdoor thermal conditions in the future Moroccan urban design. In the present work we investigate the influence of the aspect ratio (AR), on both the heat fluxes of a canyon and the thermal comfort of pedestrians for three Moroccan climatic zones (Agadir, Errachidia and Fez). At first the Town Energy Balance model coupled with a turbulence closure model is evaluated using experimental data. The model is then used for determining the influence of heat fluxes generated by the canyon surfaces on the predicted mean vote (PMV) chosen as a thermal comfort indicator. The simulations results obtained using actual Moroccan envelope building characteristics show that in the three climatic zones it is best to promote a medium urban structure to insure a comfortable street for the two cold and hot seasons. The AR must be lower than 1.2 for Errachidia, between 2.5 and 3.4 for Agadir and between 1.2 and 1.9 for Fez. However, canyons having higher AR can also insure a comfortable climate using historical thick walls with high thermal capacity.

1. Introduction

During the last two decades, Morocco is undergoing an important economic and social development and concomitantly an increase in energy consumption estimated to a yearly rate of 7% for the coming years. Part of this energy consumption results from a growing demand for HVAC in buildings destined for various uses in expanding urban centers. Outdoor thermal conditions have a great influence on indoor thermal comfort and consequently on energy demand for HVAC. On the other hand outdoor thermal comfort is becoming a growing concern in its own right, especially in urban areas because of UHI effect. In Shanghai for example an intensity of UHI of 6.5 °C was measured (IPCC, 1990), therefore during urban planning care should be taken through designs that mitigate UHI effects to promote comfortable indoor and outdoor environments with minimum energy requirements.

Urban geometry is henceforth of considerable importance in city planning and design for thermal comfort. It can be ascertained by adjusting the fundamental morphological unit of urban geometry, namely the aspect ratio (AR), defined as the ratio of the canyon height to canyon width $AR = H/W$. This ratio is an important parameter that can be used to investigate the influence of urban geometry on outdoor environments, in terms of thermal comfort and external temperature increase. Several investigations were conducted to study the impact of the AR of the street on the outdoor thermal comfort. In Ghardaia, Algeria, deep streets were more appropriate to insure a good outdoor thermal comfort (Ali-Toudert and Mayer, 2006). In

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Nomenclature

S	net solar radiation budget for (wall, road or roof) (W/m^2)
L	net infrared radiation budget for (wall, road or roof) (W/m^2)
Satm	downward direct solar radiation on an horizontal surface (W/m^2)
D	downward diffuse solar radiation on an horizontal surface (W/m^2)
$L^{\downarrow}$	downward infrared radiation on an horizontal surface (W/m^2)
H_e	sensible heat flux for urban envelopes (W/m^2)
L_e	latent heat flux for (wall, road or roof) (W/m^2)
G	conduction heat flux for (wall, road or roof) (W/m^2)
C	heat capacity of the (wall, road or roof) ($J\ m^{-3}\ K^{-1}$)
C_a	heat capacity of dry air ($J\ m^{-3}\ K^{-1}$)
ρ_a	the air density (kg/m^3)
d	thickness of the (wall, road or roof) (m)
λ_k	thermal conductivity of the kth layer of the (roof, road or wall) (W/m K)
λ	the solar zenith angle (rad)
λ_0	the zenith angle for which the sun begins to illuminate the road (rad)
θ	the angle between the sun direction and the canyon axis (rad)
θ_0	the critical canyon orientation for which the road is no longer in the light (rad)
σ	the Stefan–Boltzmann constant ($W/m^2/K^4$)
ε	emissivity of the (wall, road or roof) (–)
T	wall, road or roof temperature (K)
Tw	sunny wall temperature (K)
Tsw	shaded wall temperature (K)
Tr	road temperature (K)
TR	roof temperature (K)
T_i	the building internal temperature (K)
Tatm	the air temperature at the top building level (K)
Tcan	average temperature of the air canyon (K)
q_{can}	the average humidity of the air canyon (kg/kg)
q_{sat}	the humidity of a saturated humid air (kg/kg)
L_v	the latent heat of vaporization (J/kg))
Ta	the air temperature (K)
h	sun height (rad)
I	solar constant (W/m^2)
I_n	the direct solar radiation at normal incidence (W/m^2)
TL	the trouble of Linke (–)
X	horizontal coordinate of space (m)
Y	vertical coordinate of space (m)
U_{can}	average horizontal wind speeds of the street canyon (m/s)
W_{can}	average vertical wind speeds of the street canyon (m/s)
Re	Reynolds number (–)
u	air velocity in the direction of the x coordinate (m/s)
v	air velocity in the direction of the y coordinate (m/s)
V_c	the canyon air velocity (m/s)
α	albedo of (wall, road or roof) (–)
P	pressure (Pa)
p_a	the vapor pressure of the surrounding air (Pa)
t	time (s)
H	average building height (m)
W	street width (m)
M	the air mass (–)
M_e	the metabolic rate (W/m^2)
Li	the thermal load for a person at an activity level (W/m^2)
PMV	predicted mean vote (–)
f_{cl}	the ratio of the surface of the clothed body to the surface area of the hide body (–)
h_c	the convective heat transfer coefficient ($W/m^2\ K$)
I_{cl}	the clothing insulation ($m^2\ K/W$)
R_{cl}	the thermal resistance of clothing ($m^2\ K/W$)
t_{cl}	the average surface temperature of clothing (K)
t_r	the mean radiant temperature (K)
w_p	the external work done by the pedestrian in the street (W/m^2)