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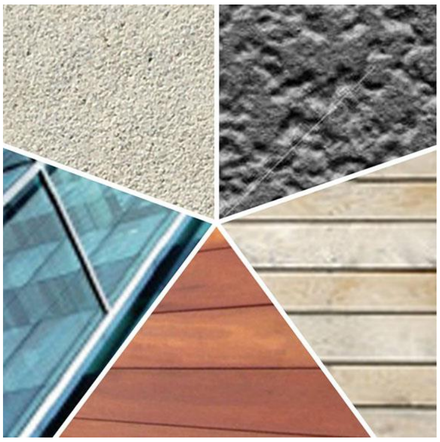
Human and Building-envelop interaction in open area - Which constructive choices to improve summery comfort?



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Abstract

Facades represent an important part of urban envelop in dense areas. They play a major role in the thermal comfort of pedestrians as well as on the city (in)-ability to stay reasonably fresh during the day or to cool at night.

This study focuses on differences in thermal comportment of different kind of vertical elements – heavy or light, pale or dark, absorbent - reflective or transparent based on measurements of different real situations.

The study shows the differences between vertical surface’s temperatures but also highlights the differences of speed at which surfaces reach their highest temperature and so the time necessary to cool after solar exposure.

Finally, it also underlines the ability of reflective surfaces (eg. glass facades) to worsen the comfort of pedestrians by adding up to 40% of incoming solar radiation intensity.

Findings from this study show that surfaces do not only affect the apparent temperature by adding up to several degrees but also to a lesser extent the urban heat island effect.

These results show the importance of material and constructive choices regarding the mitigation of exacerbation of global warming in cities.

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1. Scope

1.1 Introduction

In the current context of urban densification and global warming, climate and urban micro-climate issues are central in the concerns of construction stakeholders.

Impacting not only the comfort but also the health of city users and their ability to take full advantage of the city, these local climate issues are the subject of numerous studies which aims at improving the resilience of cities to climate change.

However, most of these studies are focused on "improving" the city-wide climate, such as addressing the urban heat island effect, and very little information is available about immediate human – built environment interactions.

The facades representing a large part of the built environment, and their constructive choices offering the greatest freedom (less constraints than the streets for example), they are then the focus of this study.

1.2 Study's goal

The main objective of this study is therefore the development of a guide, simple and illustrated with real examples measured and compared, showing the impact of the main typological families of facades on the comfort felt by a person in the immediate environment of these constructions.

2. Methods

2.1 Measurement tool – the uCM : "microclimamètre"

The main instrument used for the whole set of measure is the "microclimamètre" [1], a measurement tool developed by the LEEA – Laboratory of Energy, Environment and Architecture – at Geneva School of Engineering, Architecture and Landscape. The so called "microclimamètre" allows to measure several environmental parameters such as air temperature, surrounding surfaces temperature, solar irradiance – which were used for this study – as well as other parameters such as air quality, sound intensity, wind and so on.

The "microclimamètre" allows to take continuous measurement side by side with pictures of the surrounding environment at the exact moment of the measure. It allows to easily retrieve the exact condition at the moment of the measure and help to explain some phenomenon observed in the dataset.

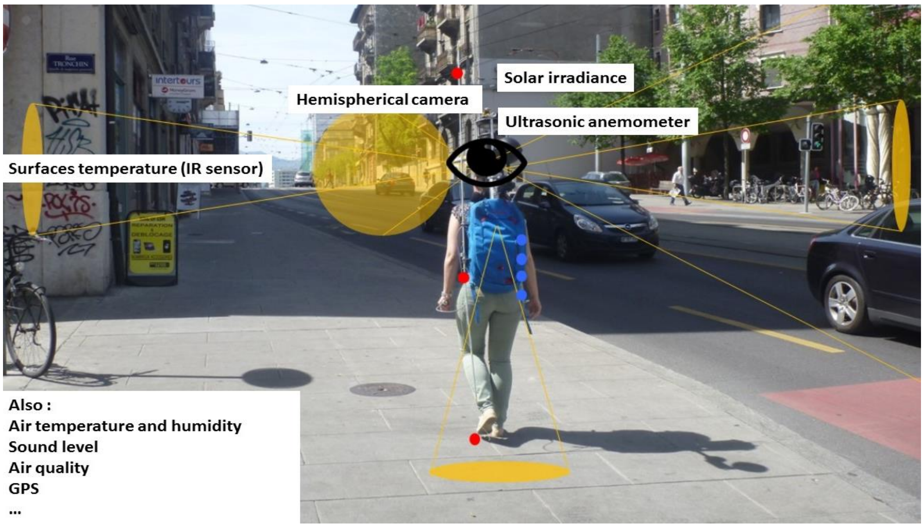

Figure 1 The "microclimamètre" tool representation

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2.2 Facade classification

As there are a large number of constructive typologies of facades, the first stage was devoted to the elaboration of a classification into a limited number of facade families. To do this the main thermal characteristics of the facades directly impacting the thermal comfort of a person in the immediate vicinity have been retained to be easily identifiable by all the actors of construction.

Once the large typological families useful for the study were defined, a phase of identification was carried out in order to select, in a real built environment (city of Geneva), a number of representative examples.

2.3 Measurement process

The focus of the study is then to measure the selected examples using the “microclimamètre” several times during a typical summer day to observe the thermal behaviour of the facades and their impact/contribution on comfort in their immediate environment. At this stage, the study focuses on the direct impact of facades on daytime comfort.

For facades thermal behaviour, measurements made in the early morning, early afternoon and late afternoon were used, while for facades direct impact with phenomenon such as direct solar reflection direct measurement where used in comparison of references taken in the near surrounding environment.

3. Results

3.1 Elaboration of facades families

The facades have been classified into 5 families, detailed in the table below, according to their thermal inertia, albedo, and their mode of reflection of incoming solar energy.

In order to remain in clear notions allowing a simple classification, the thermal inertia as well as the albedo have been simplified as being Low or High and the mode of reflection as totally Diffuse or totally Specular.

Although “in-between” exists for each of these parameters, experience shows that this simplification allows a good representation of the real cases that can be observed in the built environment.

The table 1 below shows the main families retained for the study and their principals thermal characteristics.

Table 1 Facades families and their main characteristics

	Thermal inertia	Albedo	Reflection mode
Heavy pale	High	High	Diffuse
Heavy dark	High	Low	Diffuse
Light pale	Low	High	Diffuse
Light dark	Low	Low	Diffuse
Reflective	Low to High	Medium to High	Specular

The 5th family of facades, namely the reflective facades, includes all facades having a specular reflection of the solar radiation incident, and in particular glazed facades, which also transmit a significant proportion of solar radiation directly to the interior of buildings.

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3.2 Thermal behaviour of surfaces

The study first highlighted the differences of surfaces temperature existing between the five families.

While some facades showed a surface temperature close to the one of surrounding air, the warmest ones showed temperature up to 10 to 20 degrees higher under the same environmental exposure.

This elevation of temperature was then calculated in term of impact on mean radiant temperature and on felt temperature for pedestrians, showing a difference of several degrees.

Heavy facades and reflective one showed the lowest surface temperature while light ones showed the highest.

The study also highlighted the speed at which the highest temperature for each family was recorded. While heavy facades tend to takes longer to warm up, light ones showed very fast temperature elevation.

The figure 2 bellow shows the different profile of thermal changes of the four non reflective families under heavy solar exposure, assuming that all facades will at some point reaches their maximum temperature and that surfaces have a similar emissivity, so a similar maximum temperature under the same exposure.

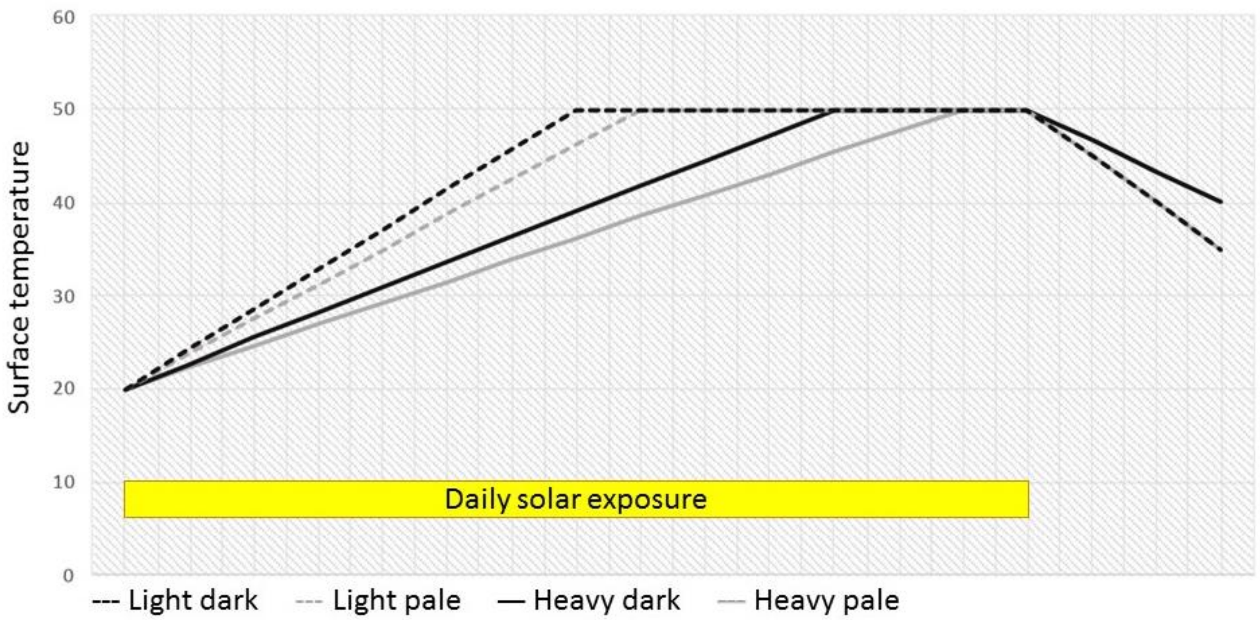

Figure 2 Surfaces temperature modification profile for the non-reflective families under heavy solar exposure.

3.3 Solar reflection

Measurements made in front of reflective facades, such as glazed one, showed an elevation of the solar radiation received at the pedestrian level up to 40% in an open environment. This phenomenon of a “second sun” perceived can considerably worsen the comfort by adding up to few degrees of felt temperature.

In narrower environment such as urban canyon, the solar radiation measured at the pedestrian level was up to three time higher by exposing the subject to a portion of the direct sun while the reference spot without solar reflection was under complete shadow. This results in an elevation of mean radiant temperature of up to 6 degrees and on the felt temperature of about 2 to 3 degrees. It also shows the impact reflective facades can have concerning radiative traps and hence on canyon radiative balance.

Pictures 3 and 4 shows to example of measured solar reflection situation due to glazed facades.

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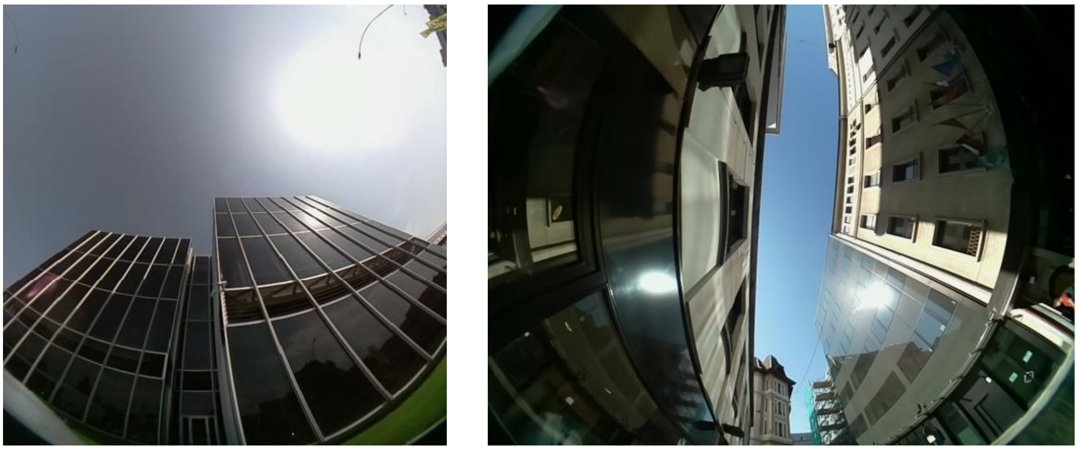

Figure 3 & 4 Solar reflection on glazed facades in an open area (figure 3) and in a narrow canyon (figure 4)

4. Discussion

The comparison of thermal dynamics between heavy and light facades underline the beneficial impact of heavy facades on daytime thermal comfort of the pedestrian. Indeed, heavy surfaces require a much greater amount of energy compared to light facades to warm up. On a sunny day, like it is the case of a summer day, the temperatures of heavy facades will be therefore less important than those of the light facades and they will provide to the pedestrian better thermal comfort. In maximum exposure conditions, probability that the temperature of a heavy facade reaching its equilibrium temperature is high, as is for light facades.

Conversely, in environments where the exposure of the facade to incoming solar radiation due to the urban geometry characterized by the sky view factor (Sky View Factor) is less, such as the urban canyon, the probability that the solar radiation equilibrium temperature of the heavy facade is reached is low. This is especially true for facades with low exposure to solar radiation, when the maximum temperature of the surface is not reached. There is therefore a real advantage to the use of heavy facades in order to improve thermal comfort in the city.

Finally, we must not neglect the nocturnal thermal impacts associated with the typology of the facade. The night-time release of the energy stored during the day is differentiated for heavy and light facades. Heavy facades will restore energy more slowly than light facades. In other words, heavy facades have a significant impact on the thermal conditions at night, as they act like radiators until they have cooled down.

Glass facades can contribute significantly to the thermal discomfort of the pedestrian. The phenomenon of double sun, which can increase the reflection of solar radiation by 30 to 40% in an open environment, can induce a significant increase in the temperature felt. If only considering the surface temperature for the radiative balance on pedestrians, they can perform as well as heavy pale facades when not exposed to the direct sun.

5. Perspectives

These day comparisons, when the temperature felt is mainly influenced by exposure to direct sunlight or not, do not take into account the night period. It would be interesting to extend this study to this nocturnal phase, when the temperature felt is mainly affected by the air temperature and the radiative environment.

Also, while this study focuses mainly on pedestrian comfort, it would also be useful to then confront these results with the impact on city ability to globally cool at night.

Literature/references

[1] https://leea.hesge.ch/index.php?article33/cityfeel