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Classification of building materials used in the urban envelopes according to their capacity for mitigation of the urban heat island in semiarid zones

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A B S T R A C T

The materials which compose the urban areas absorb solar and infrared radiation and the accumulated heat is dissipated to the atmosphere. This means that the urban envelope plays a key role in the reduction of heat gains and the city overheating. This study classifies the thermal behavior of materials used in the enveloping surfaces of the city of Mendoza, Argentina, – pedestrian pavements, tiles and vertical claddings. According to the method described by the regulation ASTM E1980, the used methodology is based on the determination of the solar reflectance and surface temperature regarding to a black and white pattern, defined as solar reflectance index (SRI). The results show that the 78% of the horizontal envelope evaluated – pedestrian pavements and tiles – has a SRI lower than 50%, and the variability between the best and the worst behavior is 30%. In the case of facades claddings the 90% of them have a SRI greater than 40% and its variability is 70%. If it is considered that, the horizontal urban envelopes present more demanding conditions related with solar exposition; and assessing their SRI values; they offer lower possibilities to improve their thermal behavior. In the case of vertical claddings, although their solar exposition is lesser, they present better possibilities for managing their thermal behavior.

The results confirm that an appropriate selection of materials which compose the urban envelopes contribute to reduce the negative effects of heat island. On the other hand, classifying their thermal behavior constitute an adequate tool in order to transfer this information to the makers of the habitat development. Therefore, the final goal is to get in the medium term the energetic and environmental urban sustainability.

1. Introduction

The presence of a city produces diverse alterations on the regional local climate, changing the albedo of the terrestrial surface and the evapotranspiration rate of the natural soil, disturbing the energy balance on the surface and the air temperature close to it. All of these effects cause that the temperatures in cities are higher than those of their surroundings giving way to the phenomenon known as “urban heat island” (UHI).

The increase of urban temperature has a direct effect on energetic and environmental sustainability of cities [1,2]. High urban temperatures raise the energy consumption for thermal conditioning in buildings during summer, decrease the habitability (degree of comfort) of open areas in the city (streets, sidewalks, squares, etc.) and reduce the potential cooling by natural convection during the night [3–9].

The Mendoza Metropolitan Area (MMA) is located in central western Argentina (32°40′ southern latitude, 68°51′ western longitude, and 750 m above sea level) in a semi-arid continental climate with low percentages of atmospheric relative humidity and high heliophany. The site corresponds to the aridity index of 0.20–0.50 (aridity index = precipitation/potential evapotranspiration) according to maps of desertification hazard of Central Western Argentina [10]. The geometry of the city, the intense forestation of the road channels, which diminishes the available sky vision and the enveloping materials, gives rise to the urban heat island, which reaches maximum values of de 10 K. (value comparable with cities like Tokyo, whose has a much higher building density than Mendoza). This produces an increase in the energy consumption of around 20% due to the cooling needs to obtain comfort conditions in the indoors spaces of the metropolitan area during summer [11] (Fig. 1a).

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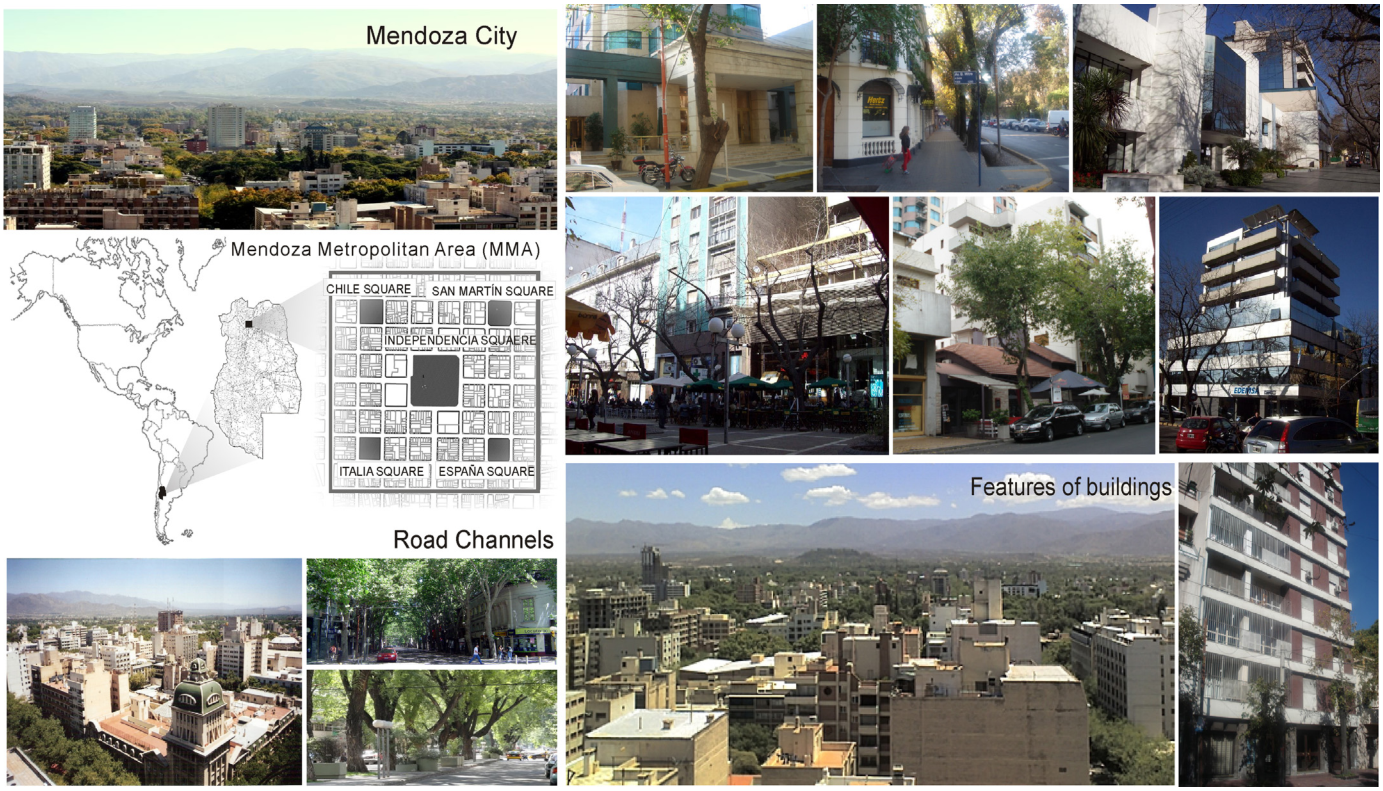

Fig. 1. Mendoza Metropolitan Area (MMA), Argentina. (a) Location map, features, morphology and forestation of the city studied. (b) Features of the selected sample space within the city.

Worldwide, the different strategies formulated to mitigate the urban heat island are sustained in two principles: increase the green coverage and work on the thermo physical properties – albedo, emissivity, rugosity, etc. – of the materials used in the resolution of urban areas [12,13]

The use of green coverage as a mitigation strategy in Mendoza city is conditioned by the fact that the water is a limited resource. The Mendoza River basin that supplies the city provides an availability of 1620 m^3/inhab/year and an estimated in 2020 will be reduced to 1150 m^3/hab/year. United Nations considers a minimum annual volume of water of 1700 m^3 per capita. Against this background, the vital and non-replaceable resource is prioritized for human consumption over the irrigation of green spaces.

Therefore in this city, with high level of solar radiation and low water availability, the use of "cold materials" seems to be a low cost and viable alternative. It may be implemented in urban areas for the construction and building rehabilitation, as strategy for reduce the negative effects of the urban heat island. This has been demonstrated in diverse papers [14–19].

The first step for the practical application of this strategy in MMA is to characterize the thermo-physical properties of urban surfaces materials. For this reason, the mean objective of this research is to classify the enveloping materials (pavements, facades and roofs) by means of the solar reflectance index (SRI) to determine their capacity to mitigate the negative effects of the urban heat island. Internationally there are a lot of papers that evaluate the thermo-physical properties of building materials [20–23]; this paper propose besides, explore which ones are the envelopes locally available that offer the better possibilities for their rehabilitation. In addition, the results obtained for the materials in terms of SRI (solar reflectance index) are correlated not only with their color but also with other features, as their composition, shape, finished and texture.

In this sense, this work classifies a group of materials used in the enveloping surfaces of the city of Mendoza, Argentina, according to the method described by the regulation ASTM E1980. The solar reflectance index (SRI) of the selected materials is based on the measurement of its solar reflectivity, its thermal emissivity and its superficial temperature. This way, it is internationally possible to compare the results of the materials behavior used locally and regionally, and at the same time, generate knowledge around the standardization of the regional materials, laying the bases to propitiate a future energetic certification both at urban and building level.

2. Methodology

2.1. Solar reflectance index (SRI)

In this research project, the ability of all evaluated materials for reduce urban temperatures has been quantified by mean the value of their SRI. The solar reflectance index (SRI) quantifies the heat, which would accumulate a material related to a white and a black pattern surface under standard environmental conditions. This method is used for surfaces with emissivities higher than 0.01 and superficial temperatures lower than 423 K [24].

The index enables a direct comparison between diverse materials of the urban envelopes with different optical properties (solar reflectance and emissivity). In order to determine the efficiency of each of them for mitigate the urban heat island.

It is calculated by using equations based on values of reflectance and solar emittance. It is expressed as a value (0.0–1.0) or as a percentage (0–100%). For a surface exposed to sun and isolated