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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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ABSTRACT

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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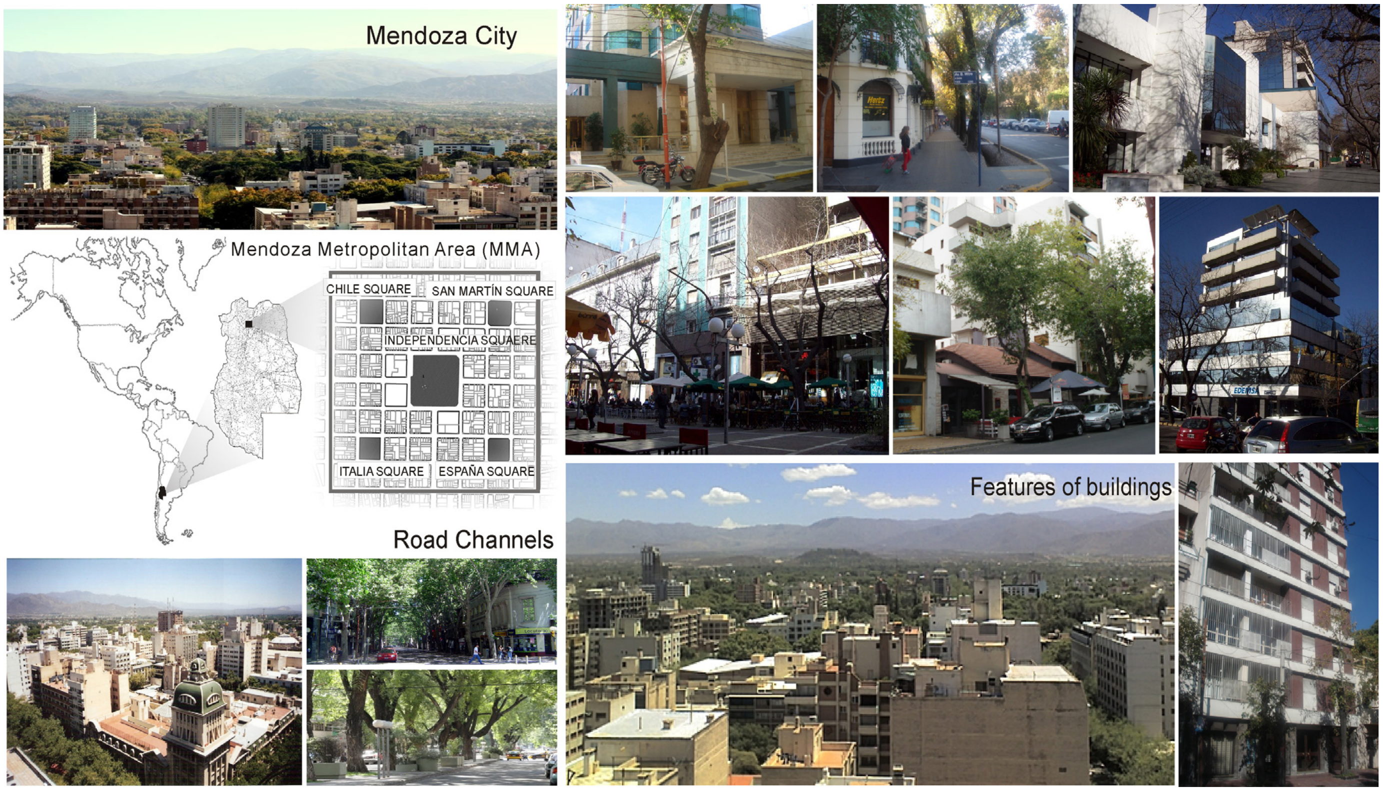

Fig. 1. Mendoza Metropolitan Area (MMA), Argentina. (a) Location map, features, morphology and forestation of the city studied. (b) Features of the selected sample space within the city.

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

underneath, the superficial temperature of equilibrium (T_s) is obtained as from ASTM E1980-11:

$$T_s = 309.07 + \frac{1066.07\alpha - 31.98\varepsilon}{6.78\varepsilon + h_c} - \frac{890.94\alpha^2 + 2153.8\alpha\varepsilon}{6.78\varepsilon + h_c} \quad (1)$$

where:

α = solar absortance = 1 − solar reflectance
I = solar flux, W / m^2
ε = thermal emissivity
σ = Stefan Boltzmann constant, 5.66961×10^{-8} W m^{-2} K^{-4}
T_s = steady-state surface temperature, K
T_{sky} = sky temperature, K
h_c = convective coefficient, W m^{-2} K^{-1}
T_a = air temperature, K

Therefore, the solar reflectance index is defined as:

$$\text{SRI} = 100\frac{T_b - T_s}{T_b - T_w} \quad (2)$$

where:

T_b = black pattern temperature, K
T_w = white pattern temperature, K
T_s = steady-state surface temperature, K

By means of Eq. (1), the superficial temperatures of the patterns are calculated under local environmental conditions, according to regulations.

2.2. Emissivity and solar reflectance of materials

The thermal performance of the materials is determined mainly by their optical and thermal properties. The solar reflectance and the thermal emissivity are the most important factors [25,26]. To classify a materials according their SRI is needed previously knowledge their optical properties (solar reflectance and emissivity).

The value of the emissivity is obtained – according to the ASTM 1933-99a – when the temperature registered by a T type thermocouple and the superficial temperature measured by IR thermometer Fluke 568 are similar [27]. The radiant energy registered by the infrared chamber for determine the materials surface temperature does not only depend on the object temperature but also its emissivity (ε). Then the value of emissivity obtained for each sample was set into the IR camera for the measurements the surface temperature.

The solar reflectance measurement according ASTM E1918 only may be used when the target is at least 10 m^2 in area and roughly square or circular in shape. The difficulty of transporting such large samples for the natural – exposure makes the sample-size requirements of E1918 costly and inconvenient. Therefore, in this study has been used a method (variant to ASTM E1918) proposed by Akbari et al. [28]. This method measures the solar reflectance of materials samples of about 1 m^2 using a pyranometer and a pair of black and white masks [28] Besides, use a single pyranometer for solar reflectance measurements is economical, but introduces additional uncertainties associated with the inversion of instrument [29]. For these reasons we have opted to use a two pyranometers system to determine the solar reflectance value ($\hat{a}$), where both pyranometers are Kipp & Zonen CM3 type, the set is named albedometer. The albedometer registers the solar radiation which is received over the horizontal surface and the reflected solar radiation. The solar reflectance of each material is determined by difference [30]. The radiative spectrum covered by the instrument is 285–2800 nm, and a maximum solar irradiance of 4000 W/m^2. Their nominal sensitivities it is 1.5×10^{-6} V/Wm^{-2}. The stated response time (95%) it is 18 s.

The thermal conductivity has not been considered because all samples have similar thicknesses. Besides, the layer of expanded polystyrene works as adiabatic limit regarding the grounding conductivity.

2.3. Test method

The solar reflectance, emissivity and superficial temperature were registered during summer of 2010–2011. Measurement of the solar reflectance and emissivity were recorded during the second and third week of January 2010. Superficial temperature of tiles and pedestrian pavement were registered in February 2nd, 3rd and 11th, 2010. And superficial temperature of vertical claddings was measured in February 7th, 8th, 22nd and March 10th, 2011. From the series of measurements, the values reported in this study correspond to February 11th, 2010 and March 10th, 2011; being days in standard environmental conditions. The values were recorded at 13:00 h and were used to calculate the SRI following the ASTM E1980-11.

During the monitoring period, the meteorological measurements were:

- February 11th, 2010: solar radiation 1009 W/m^2, average air temperature 305 K; average relative humidity of 25% and average wind speeds 2 m/s.
- March 10th, 2011: solar radiation 916 W/m^2, average air temperature 303 K; average relative humidity of 25% and average wind speeds 2 m/s.

These measurements were taken on the site by means of ONSET Weather Station, type HOBO®, model: H21-001. Its operative range is between 253 K and 323 K.

As was said previously, in this experience for surface temperature measurements was used the IR chamber Fluke Ti 55, which detects the infrared radiation of long wave in the range of 7.5–14 μm within the electromagnetic spectrum. In thermo graphic pictures, each pixel contains certain temperature value [31] .The software Smart-View 2.1 through algorithms, assigns a specific color corresponding to a temperature value in the $x-y$ coordinate of the image. The values of surface temperatures obtained were average for each material analyzed (Fig. 4). Besides, a set of Data Logger and thermocouples T-type, model Akribis TPD8356 were used for verifying the values of surface temperatures obtained from the IR camera.

2.4. Sample unit

The study takes place in the city of Mendoza, Argentina – an urban conglomerate close to a million people located in a seismic and an semi-arid zone. It presents an open urban geometry, formed by wide streets and a heavily forested building structure. The city has a pyramidal shape: the high building density is concentrated in the center of town and diluted to the periphery where is located the low density.

Conceptually the building's designs respond to its climate adaptation, in some cases. They are the result from the application of traditional elements available regionally and technologies associated with seismic character of the site – bare brickwork, reinforced concrete. In others cases, the buildings reply to formal trends resulting from the use of new technologies – steel and glass – regarding roofs, dominates the flat condition in the buildings and tilted with different materials and colors in residential areas of low density. The vertical facades are composed by bare brickwork and rustic or smooth cladding.

The urban areas present the same appearance of the others current cities: asphalt or concrete pavement and sidewalks with a wide range of materials: concrete and stone, with clear colors in the past and a strong tendency to the use of dark colors nowadays. Into de

Fig. 2. Thermal and optical evaluation of materials in the study site.

city, pavements represent 40%, sidewalks 15% and roof 22% of the urban envelopes [32].

This report studies the thermo-physical behavior of pedestrian pavements, tiles and vertical claddings of facades taking into account the most used materials and the new tendencies (Fig. 1b).

2.5. Material selection and classification

Through the survey of the horizontal envelopes materials in MMA, we find 9 types of pedestrian pavement. Approximately 80% of the total is formed mainly by *Smooth concrete/calcareous* pavement: red (30%), yellow (25%), black (13%), gray (9%) and white (5.7%). They are followed by *Rustic concrete/stone-boulder flat* (18%) and a smaller percentage of *Smooth natural stone-mosaic flat* (black and reddish tones).

With respect to the roofs, predominate the use of ceramic tiles-type French and Colonial – over the fiber cement tiles, especially in terracotta color and in lesser measure black.

The study samples are: 44 pedestrian pavements, 16 kinds of tiles, and 80 vertical claddings (acrylic and concrete).

Samples of pavements and tiles were placed on a horizontal surface of 7 cm thick of expanded polystyrene, acting as an adiabatic limit regarding the conductivity of the material to the ground. The vertical coatings – blocks of 30 cm × 30 cm – were formed by three layers: support isolation (10 cm thick of high-density expanded polystyrene), a 3 mm mortar is extended, enabling a better adherent to the cladding to the polystyrene surface and, lastly, the layer of textured and colored cladding (Fig. 2).

These samples are located in the Regional Center of Scientific and Technical Researcher, in the west area of the city (32°53′ latitude, 68°51′ western longitudes).

The pedestrian pavements were classified according to its composition, texture, color, shape and sub-shape. Tiles were characterized according to its composition, texture, color and shape. For more details see Fig. 3.

The vertical textured claddings (quoted according to the manufacturer's labeling) are differentiated according to their composition in: acrylic (SIP) and concrete (CW). The first ones – SIP – are composed with acrylic polymers, mineral loads, and inorganic pigments with high UV resistance and chemical additives.

The concrete claddings CW are composed with white concrete, spur stone, lime, pigments, organic and inorganic additives, mineral loads, synthetic resins, fungicides and algaecides in powder.

In this stage, six textures of different particle sizing and finish were select, according to the demand in the local market and frequency use. In the acrylic claddings – SIP: *Travertine rulato* both *fine* (fr) and *rustic* (rr), *Llaneado* both *rustic* (fl) and *fine* (rl), and *Medium granitex* (mg). In the concrete claddings – CW: *Rulato textured* (mr), *Travertine textured* (mt), *Salpicrete* both *salpic* (ss) and *ironed* (is), and *Medium granitex* (mg). In the 8 most-demanded colors: White, ivory, paris stone, ochre, terracotta, clear gray, jade green and dark gray (Fig. 3).

3. Results

The results are presented in the following form:

- Values of albedo, emissivity, superficial temperature and the solar reflective index (SRI) for the three types of envelopes: pavement, tiles and vertical cladding in a table form (Section 3.1: Tables 1–3).
- Thermal behavior and the solar reflective index (SRI) for each envelope type:
  - *Pedestrian Pavement* is analyzed according to: comparison between extreme cases; differences by color, and shape (see Section 3.2).
  - *Tile* is analyzed according to: comparison between extreme cases; difference by composition, finishes, color, and shape (see Section 3.3).
  - *Vertical Cladding* is analyzed according to: comparison between extreme cases; differences by composition, finishes and textured, color (see Section 3.4).
- Comparative analysis of thermal behavior of pavements and tiles most used in the city in relation with the most efficient materials studied (see Sections 3.5 and 3.6).

3.1. SRI of materials

See Tables 1–3.

3.2. Pedestrian pavements: analysis of the thermal behavior and the SRI

3.2.1. Comparison between extreme cases

The better material seems to be the granite mosaic flat travertine smooth-P34 with a surface temperature of 323 K and a SRI equal to75%. The second and third places are the smooth natural stone-mosaic flat-gra-P25 and smooth concrete/stone and alucía circular-gray/multicolor-P13 (surface temperature: 333 K, 334.5 K respectively). The worse pavement seems to be the smooth concrete/calcareous-single line straight-black-P35, with a surface temperature of 346.5 K and the SRI of 28%. The second are the Rustic concrete-square straight-black-P07, and the Rustic concrete-and alucía circular-black-P27.

In the two extreme analyzed cases, P35 and P34, pavement *Smooth natural stone-mosaic flat-travertine*-P34, has 47% more capacity to mitigate the effects of the heat island than *Smooth concrete/calcareous-single line straight-black*-P35. Its surface

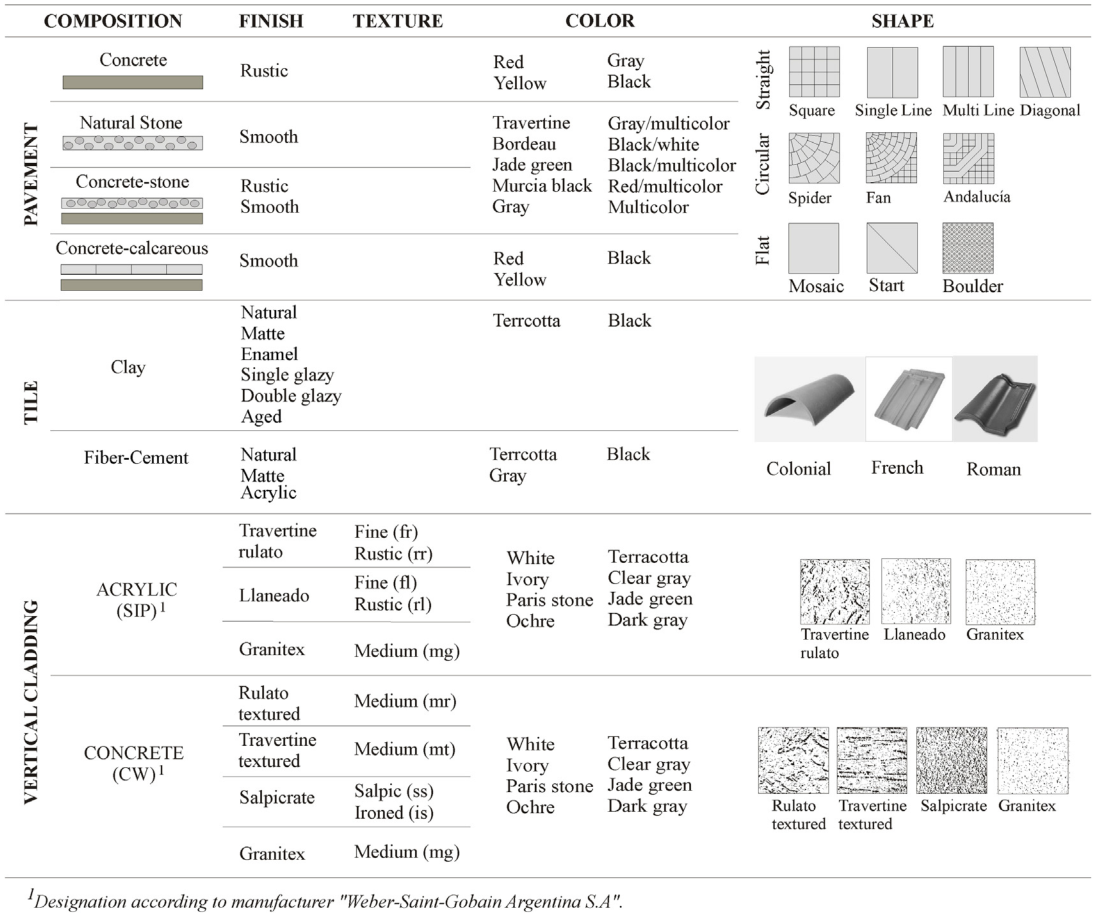

Fig. 3. Materials classification (pedestrian pavements, tiles and vertical claddings) according to its composition, finish-texture, color and shape.

temperature difference is 23.5 K. The higher level of reflectivity is achieved by the cooler option P34 with an albedo of 0.76.

3.2.2. Differences by color

When comparing the color of the *Smooth concrete/calcareous-single line straight*: red-P36-black-P35 and yellow-P37, and multiline straight yellow: P38 (higher diffusion in MMA), is obtained as a result that the floor black-P35 is the one reaching higher temperatures. Its temperature is 6.5 K higher than the calcareous red and 7.5 K higher than the yellow one. The black floor obtains an index of 28%, while the red and yellow floors do not show significant differences (41% and 42–42.5% respectively).

The *Rustic concrete/stone-boulder flat* is the second pavement more use in MMA. When comparing the different colors P6 vs. P16 (*Rustic concrete/stone-boulder flat-gray*, *Rustic concrete/stone-boulder flat-multicolor*), we find that this variable does not condition substantially its thermal behavior P6 = 338 K; P16 = 338.5 K. The SRI values are of 45% in the first case and of 44% in the second one.

Among the *Smooth natural stone-mosaic flat* pavement, four cases of different colors were studied: travertine-P34, gray-P25, jade green-P31, and murcia black-P29. It was observed that murcia black P29 registers the highest temperatures. Its value is 22 K higher than in travertine P34, 12 K higher than in the gray pavement-P25, and 4 K higher than in jade green color-P31. Travertine floor-P34 reaches a reflectance index of 75%, while murcia black-P29 does not exceed 30%.

3.2.3. Differences by shape

The Rustic concrete-spider circular-black-P2- type, has lesser temperature than the Rustic concrete- fan circular- black-P05, Rustic concrete- mosaic flat- black-P19, Rustic concrete- square straight- black-P33, Rustic concrete- square straight-black-P7, and Rustic concrete-andalucía circular-black-P27.

For a same color (black) and finish (rustic concrete), the difference is approximately 4 K. The reflectance index value varies between 30% and 37% (Table 1).

3.3. Tiles: Analysis of the thermal behavior and the SRI

3.3.1. Comparison between extreme cases

In the case of the tiles, three types are detected with higher capacities to mitigate the urban heat island. These are: tile *Enamel clay-roman-terracotta*-T08 with a surface temperature of 327 K and SRI equal to 67%; in second and third place, we have tile *Enamel clay-french-terracotta*-T03, and *Natural clay-colonial-terracotta*-T01.

In the case of fiber-cement tiles, *Natural fiber cement-french-gray*-T14 is the most efficient. It is characterized by: SRI = 63%, surface temperature = 329 K, albedo = 0.63 and emissivity = 0.90.

The tiles that contribute to increase the UHI are: *Acrylic fiber cement-french-black*-T13, with a surface temperature of 342 K and SRI of 37%, the *Matte fiber cement-french-black*-T12, and finally the tile *Single matte clay-french-black*-T07.

In addition the *Enamel clay-roman-terracotta*-T08-tile, diminishes 15 K respects to *Acrylic fiber cement-french-black*-T13. The colder tile-T08 is characterized by: albedo = 0.67 and emissivity = 0.85.

3.3.2. Difference by composition: clay vs. fiber-cement

Clay tiles show in the most of the cases a better thermal performance than fiber-cement ones. For example:

Table 1
Assigned code, superficial temperature (K), albedo, emissivity and SRI of pedestrian pavements.

Pedestrian pavement		â	ε	T_s (K)	SRI (%)	Pedestrian pavement		â	ε	T_s (K)	SRI (%)
P01	Rustic concrete-fan circular-gray	0.53	0.90	340	41	P20	Rustic concrete-square straight-gray	0.56	0.90	337.5	46
P02	Rustic concrete-spider circular-black	0.49	0.95	342	37	P21	Smooth concrete/stone-andalucía circular-jade green	0.51	0.95	340.5	40
P03	Rustic concrete-andalucía circular-red	0.53	0.95	339	44	P22	Smooth Concrete/stone-square straight-black/white	0.47	0.95	343	35
P04	Rustic-concrete-fan circular-red	0.56	0.90	338	41.5	P23	Smooth concrete/stone-andalucía circular-murcia black	0.48	0.90	344	33
P05	Rustic concrete-fan circular-black	0.47	0.95	343	34	P24	Smooth concrete/stone-square straight-bordeau	0.55	0.90	338	44.5
P06	Rustic concrete/stone-boulder flat-gray	0.56	0.90	338	45	P25	Smooth natural stone-mosaic flat-gray	0.64	0.85	333	56
P07	Rustic concrete-square straight-black	0.43	0.95	346	30	P26	Smooth concrete/stone-andalucía circular-black/multicolor	0.48	0.90	343.5	34
P08	Rustic concrete-spider circular-gray	0.55	0.90	338	45	P27	Rustic concrete-andalucía circular-black	0.42	0.98	346	30
P09	Rustic concrete-spider circular-red	0.54	0.90	339	43	P28	Smooth concrete/stone-square straight-red/multicolor	0.54	0.90	340	42
P10	Smooth concrete/stone-fan circular-murcia black	0.47	0.95	343	34	P29	Smooth natural stone-mosaic flat-murcia black	0.46	0.90	345	30
P11	Smooth concrete/stone-andalucía circular-black/white	0.48	0.90	344	34	P30	Smooth concrete/stone-square straight-gray/multicolor	0.57	0.90	337	47
P12	Smooth concrete/stone-square straight-murcia black	0.46	0.95	344	33	P31	Smooth natural stone-mosaic flat-jade green	0.51	0.90	341	39
P13	Smooth concrete/stone-andalucía circular-gray/multicolor	0.62	0.85	334.5	52	P32	Smooth concrete/stone-square straight-jade green	0.46	0.90	345.5	30
P14	Rustic concrete-diagonal straight-yellow	0.55	0.90	339	43.5	P33	Rustic concrete-square straight-black	0.45	0.95	345	31
P15	Rustic concrete-mosaic flat-red	0.52	0.95	339	42	P34	Smooth natural stone-mosaic flat-travertine	0.76	0.80	323	75
P16	Rustic concrete/stone-boulder flat-multicolor	0.55	0.90	338.5	44	P35	Smooth concrete/calcareous-single line straight-black	0.42	0.95	346.5	28
P17	Rustic concrete-start flat-yellow	0.54	0.90	339	42.5	P36	Smooth concrete/calcareous-single line straight-red	0.53	0.90	340	41
P18	Rustic concrete-start flat-gray	0.57	0.90	336.5	48	P37	Smooth concrete/calcareous-single line straight-yellow	0.54	0.90	339	42
P19	Rustic concrete-mosaic flat-black	0.44	0.95	345	31	P38	Smooth concrete/calcareous-multiline straight-yellow	0.54	0.90	339	42.5

Natural clay-colonial-terracotta-T01 behaves better than *Matte fiber cement-colonial-terracotta*-T16. Temperature differences between both options are approximately 3 K. Clay tile has a solar reflectance index of 64%, while fiber-cement one reaches 57%.

Its interesting remark that light colors improve the thermal performance of fiber-cement tiles. i.e. the surface temperature of T14 (*Natural fiber cement-french-gray*) is similar to T03 (*Enamel clay-french-terracotta*) ($T_s = 329$ in both cases).

3.3.3. Difference by finish

Comparing *Clay-roman-terracotta* tiles, type natural, enamel and aged, and *Clay-french-terracotta* tiles, type natural and enamel, we find that enamel present the best SRI reaching values of 10% higher than the others (T08-T09-T10 and T02-T03 in Tables 2 and 3).

Contrasting *Clay-french-black* tiles, type mate and glazy (single or double finished), their SRI are similar (46 to 48%). It is detected minor differences associated with the manufacturing process: Double finished is better than single finished (T04-05-06-07 in Table 2).

Table 2
Assigned code, superficial temperature (K), albedo, emissivity and SRI of tiles.

Tile		â	ε	T_s (K)	SRI (%)	Tile		â	ε	T_s (K)	SRI (%)
T01	Natural clay-colonial-terracotta	0.64	0.90	329	64	T09	Natural clay-roman-terracotta	0.58	0.90	332	57
T02	Natural clay-french-terracotta	0.60	0.90	331	59	T10	Age clay-roman-terracotta	0.58	0.94	332	57
T03	Enamel clay-french-terracotta	0.64	0.90	329	64	T11	Natural fiber cement-colonial-terracotta	0.50	0.95	336.5	48
T04	Double glazy clay-french-black	0.50	0.95	336	48	T12	Matte fiber cement-french-black	0.44	0.95	340	41
T05	Single glazy clay-french-black	0.48	0.98	337	46.5	T13	Acrylic fiber cement-french-black	0.40	0.95	342	37
T06	Double matte clay-french-black	0.49	0.98	337	48	T14	Natural fiber cement-french-gray	0.63	0.90	329	63
T07	Single matte clay-french-black	0.48	0.95	337.5	46	T15	Matte fiber cement-colonial-black	0.53	0.95	334	52.5
T08	Enamel clay-roman-terracotta	0.67	0.85	327	67	T16	Matte fiber cement-colonial-terracotta	0.57	0.95	332	57

Table 3
Assigned code, superficial temperature (K), albedo, emissivity and SRI of vertical claddings.

Vertical cladding		â	ε	T_s (K)	SRI (%)	Vertical cladding		â	ε	T_s (K)	SRI (%)
SIP 1	Fine travertine rulato-white	0.86	0.85	312	97	CW 41	Medium rulato textured-white	0.86	0.90	311.5	98
SIP 2	Fine travertine rulato-ivory	0.91	0.90	308	100	CW 42	Medium rulato textured-ivory	0.77	0.85	317	88
SIP 3	Fine travertine rulato-paris stone	0.81	0.88	314	92	CW 43	Medium rulato textured-paris stone	0.69	0.80	322	77
SIP 4	Fine travertine rulato-ochre	0.47	0.95	332	57	CW 44	Medium rulato textured-ochre	0.51	0.85	332	58
SIP 5	Fine travertine rulato-terracotta	0.41	0.95	336	50	CW 45	Medium rulato textured-terracotta	0.49	0.93	332	58
SIP 6	Fine travertine rulato-clear gray	0.57	0.85	329	64	CW 46	Medium rulato textured-clear gray	0.61	0.82	327	68
SIP 7	Fine travertine rulato-green	0.40	0.95	336	49	CW 47	Medium rulato textured-green	0.42	0.95	335	51.5
SIP 8	Fine travertine rulato-dark gray	0.28	0.95	342	37	CW 48	Medium rulato textured-dark gray	0.32	0.95	340.5	41
SIP 9	Rustic travertine rulato-white	0.78	0.85	316	89	CW 49	Medium travertine textured-white	0.53	0.85	331	60
SIP 10	Rustic travertine rulato-ivory	0.86	0.90	311	99	CW 50	Medium travertine textured-ivory	0.76	0.85	318	86
SIP 11	Rustic travertine rulato-paris stone	0.82	0.90	314	94	CW 51	Medium travertine textured-paris stone	0.69	0.90	321	79
SIP 12	Rustic travertine rulato-ochre	0.42	0.95	335	51.5	CW 52	Medium travertine textured-ochre	0.60	0.90	326	69
SIP 13	Rustic travertine rulato-terracotta	0.29	0.94	342	38	CW 53	Medium travertine textured-terracotta	0.44	0.95	334	53
SIP 14	Rustic travertine rulato-clear gray	0.47	0.95	333	56	CW 54	Medium travertine textured-clear gray	0.68	0.90	322	78
SIP 15	Rustic travertine rulato-green	0.37	0.95	338	46	CW 55	Medium travertine textured-green	0.50	0.90	332	58
SIP 16	Rustic travertine rulato-dark gray	0.29	0.95	342	38	CW 56	Medium travertine textured-dark gray	0.46	0.90	334	54
SIP 17	Fine llaneado-white	0.81	0.80	315	91	CW 57	Salpic salpicrate-white	0.80	0.85	315	91
SIP 18	Fine llaneado-ivory	0.48	0.85	333	55	CW 58	Salpic salpicrate-ivory	0.79	0.90	315	91
SIP 19	Fine llaneado-paris stone	0.91	0.90	309	100	CW 59	Salpic salpicrate-paris stone	0.66	0.90	323	76
SIP 20	Fine llaneado-ochre	0.83	0.90	313	95	CW 60	Salpic salpicrate-ochre	0.55	0.95	328	65
SIP 21	Fine llaneado-terracotta	0.39	0.95	337	48	CW 61	Salpic salpicrate-terracotta	0.57	0.90	328	66
SIP 22	Fine llaneado-clear gray	0.76	0.90	317	87	CW 62	Salpic salpicrate-clear gray	0.70	0.85	321	79
SIP 23	Fine llaneado-green	0.35	0.95	339	45	CW 63	Salpic salpicrate-green	0.48	0.90	333	56
SIP 24	Fine llaneado-dark gray	0.19	0.95	347	29	CW 64	Salpic salpicrate-dark gray	0.33	0.90	341	41
SIP 25	Rustic llaneado-white	0.83	0.85	314	94	CW 65	Ironed salpicrate-withe	0.83	0.80	314	94
SIP 26	Rustic llaneado-ivory	0.73	0.85	319	83	CW 66	Ironed salpicrate-ivory	0.73	0.85	319	83
SIP 27	Rustic llaneado-paris stone	0.54	0.85	330	61.5	CW 67	Ironed salpicrate-paris stone	0.60	0.85	327	68
SIP 28	Rustic llaneado-ochre	0.72	0.90	319	83	CW 68	Ironed salpicrate-ochre	0.48	0.95	332	58
SIP 29	Rustic llaneado-terracotta	0.46	0.95	333	56	CW 69	Ironed salpicrate-terracotta	0.44	0.95	334	54
SIP 30	Rustic llaneado-clear gray	0.73	0.90	319	83	CW 70	Ironed salpicrate-clear gray	0.65	0.85	324	73
SIP 31	Rustic llaneado-green	0.30	0.95	341	39	CW 71	Ironed salpicrate-green	0.46	0.90	334	54
SIP 32	Rustic llaneado-dark gray	0.23	0.95	345	33	CW 72	Ironed salpicrate-dark gray	0.31	0.95	341	40
SIP 33	Medium granitex-white	0.86	0.85	312	97.5	CW 73	Medium granitex-white	0.81	0.85	314	92
SIP 34	Medium granitex-ivory	0.76	0.85	318	86	CW 74	Medium granitex-ivory	0.75	0.85	318	85
SIP 35	Medium granitex-paris stone	0.65	0.85	324	73	CW 75	Medium granitex-paris stone	0.72	0.90	320	82
SIP 36	Medium granitex-ochre	0.70	0.90	320	80.5	CW 76	Medium granitex-ochre	0.49	0.90	332	57
SIP 37	Medium granitex-terracotta	0.39	0.95	337	49	CW 77	Medium granitex-terracotta	0.49	0.90	332	57
SIP 38	Medium granitex-clear gray	0.46	0.92	334	54	CW 78	Medium granitex-clear gray	0.70	0.80	322	78
SIP 39	Medium granitex-green	0.34	0.95	339	43	CW 79	Medium granitex-green	0.45	0.90	334.5	53
SIP 40	Medium granitex-dark gray	0.26	0.95	343	35	CW 80	Medium granitex-dark gray	0.69	0.95	320.5	80

In the case of fiber-cement tiles, the acrylic finish in the glazy tiles seems to worsen the thermal behavior compared to those that have matte finishing. i.e. *Acrylic fiber cement-french-black*-T13 has a SRI of 37% and *Matte fiber cement-french-black*-T12 has a SRI of 41%.

These results show that in the thermal behavior of tiles, the finishing is not a significative variable in case of clay french black tiles and it is more relevant in the case of clay roman terracotta tiles.

3.3.4. Difference by color

Black tiles show the highest surface temperature; their ranges are between 336 and 342 K. The tile *Matte fiber cement-french-black*-T12 reaches 340 K, while temperature in the same tile gray color: *Natural fiber cement-french-gray*-T14 is 11 K lower. The SRI value is 41% in the black one and 63% in the gray one.

3.3.5. Difference by shape

According to its classification by shape, romans tiles of different colors and finishes reach superficial temperatures from 327 K to 332 K, while colonial tiles cover a range between 329 K and 336.5 K; and french ones, 329 to 342 K. For example, *Matte fiber cement-french-black*-T12-tile increases its superficial temperature 6 K more than colonial one-T15.

Setting color and finish it is found that colonial shape show the best performance in terms of superficial temperature and SRI. (T01, T02 and T09 in Table 2).

3.4. Vertical claddings: analysis of the thermal behavior and the SRI (Fig. 5a and b)

3.4.1. Comparison between extreme cases

3.4.1.1. Acrylic cladding (SIP). The materials which have better SRI – more capacity to reduce the heating loads in the city are: *Fine travertine rulato-ivory*-SIP02 and *Fine llaneado-paris stone*-SIP19. They present a surface temperature around of 308 K and a SRI of 100%.

The SIP claddings that show worse behavior are: *Fine llaneado-dark gra*-SIP24 with a surface temperature of 347 K and a SRI of 29% and *Rustic llaneado-dark gray*-SIP32 (T_s = 345 K; SRI = 33%).

The difference between the best claddings and the worst cladding is 71% in their capacity to mitigate the effects of UHI and 39 K on their thermal behavior.

3.4.1.2. Concrete cladding (CW). The materials which have better SRI – more capacity to reduce the heating loads in the city are: *Medium rulato textured-white*-CW41 and *Ironed salpicrate white*-CW65. They present a surface temperature of 311.5 K and 314 K respectively. Their SRI are: 98% and 94%.

The CW claddings that show worse behavior are: *Ironed salpicrate dark gray*-CW72 with a surface temperature of 341 K and a SRI of 40%; and *Salpic salpicrate dark gray*-CW64 (T_s = 341 K, SRI = 41%).

The difference between the best cladding and the worst cladding is 58% in their capacity to mitigate the effects of UHI and 29.5 K on their thermal behavior (Figs. 4–6).

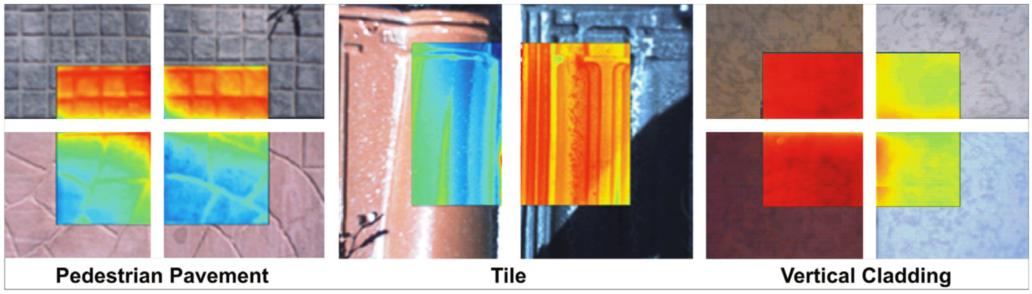

Fig. 4. Examples of the images recorded by the IR camera.

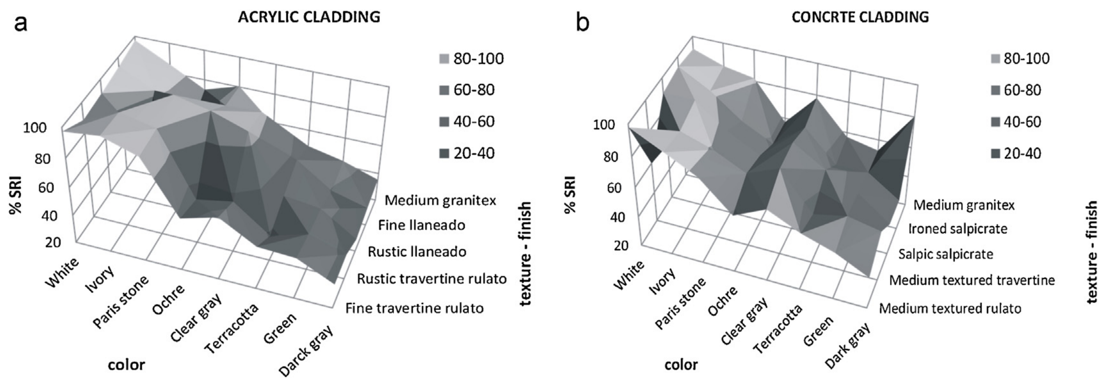

Fig. 5. Solar reflectance index (a) SRI of acrylic claddings, according to classification. (b) SRI of concrete claddings, according to classification.

3.4.2. Difference by composition: acrylic claddings (SIP) vs. concrete claddings (CW) (Fig. 6)

The 43% of acrylic claddings and 28% of the concrete claddings are a SRI = 80–100%. The 7.5% of acrylic claddings and 30% of the concrete cladding are a SRI = 60–80%. It is observed that the 32.5% of acrylic claddings and 40% of the concrete claddings evaluated are set in the range of 60–40% of SRI. While the other 17.5% of acrylic and 2.5% of the concrete have less than 40% of SRI.

With the goal to evaluate the effect of the cladding composition, it is analyzed comparatively the case of *Acrylic Medium granitex* vs. *Concrete Medium granitex:*

In light colors (*white*, *ivory* and *ochre*), the acrylic cladding (SIP) shows better thermal performance than the concrete cladding (CW). For example the surface temperature of *Medium granitex-ochre*-SIP36 is 12 K lesser than *Medium granitex-ochre*-CW 76 and its SRI is 23.5% greater. In *paris stone*, *terracotta*, *light gray*, *green*, and *dark gray* colors, which have lower albedos, this trend is inverted. That is, in these colors, the concrete cladding has better performance than acrylic to mitigate the effects of the UHI. For example the SRI in *Medium granitex-dark gray*-CW 80 is 80% while in *Medium granitex-dark gray*-SIP 40 is 35%.

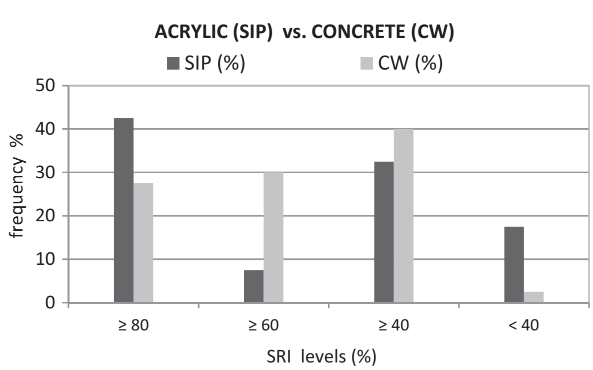

Fig. 6. Solar reflectance index according to cladding composition (SIP-CW).

3.4.3. Differences by finish and texture

Finishes and textures have different impact in the thermal performance of cladding depending of its color.

This impact could be classified in three ranges:

Range 1: the SRI varies between the different textures and finishes evaluated around 40% for the same color.

Range 2: the SRI varies between the different textures and finishes evaluated around 20% for the same color.

Range 3: the SRI varies between the different textures and finishes evaluated around 10% for the same color.

3.4.3.1. Acrylic cladding (SIP). Into the range 1 are the colors *ivory, paris stone, ochre* and *light gray*; into range 2 is *terracotta* and into range 3 are *white, green and dark gray*. These ranges show that thermal behavior of light and dark claddings colors (*white* and *dark gray*) are little influenced by the texture and finish, while intermediate colors have significative differences associated to these variables. For example *Fine llaneado-paris stone*-SIP 19 (T_s = 309, SRI = 100%) vs. *Rustic llaneado-paris stone*-SIP 27 (T_s = 330, SRI = 61.5%). In this case the surface temperature difference is the 21 K and the SRI difference 38.5%.

Fine travertine rulato finish has better thermal performance associated to fine texture for all evaluated colors, while in the *Fine llaneado* finish the effect of texture shows not a dominant tendency and the thermal behavior is commanded by the color. For example *Rustic llaneado-ivory*-SIP26 shows a SRI = 83% vs. *Fine llaneado-ivory*-SIP 18 SRI = 55%; in the contrary the *Rustic llaneado-paris stone*-SIP27 shows a SRI = 61.5% vs. *Fine llaneado-paris stone*-SIP 19 SRI = 100%.

3.4.3.2. Cladding (CW). Into the range 1 are the colors white and light gray; into range 2 are *terracotta*, *paris stone* and *ochre*, and into

range 3 are *ivory*, *light gray* and *green*. These ranges show that thermal behavior of light and dark claddings colors (*white* and *dark gray*) are strongly influenced by the finish and texture, while intermediate colors have little differences associated to these variables. For example Range1: *Medium rulato textured-white*-CW41 (T_s = 311.5 K, SRI = 98%) vs. *Medium travertine textured-white*-CW49 (T_s = 331 K, SRI = 60%). In this case the surface temperature difference is the 19.5 K and the SRI difference 38%.

In *terracotta*, *ochre* and *dark gray* colors; it is observed that the thermal performance is influenced by all finishes in different degrees. In *white*, *ivory*, *paris stone*, *light gray* and *green* colors, the thermal behavior, in general, is not influenced by the finishes. For these colors, only one finish and texture shows a significant deviation in their thermal behavior. For example *white* color in *travertine* finish-CW49 (T_s = 331 K, SRI = 60%) and this color in the rest of finishes presents an average SRI of 94%.

It is observed a particular behavior in the case of *Medium travertine textured-white*-CW49; the temperature of this cladding is lower than the rest of the finishes and texture in the above mentioned color, with a reflectance index not exceeding 60%. In the rest of the textures with *white* tonalities reaches an average of 92% (see CW41, CW57, CW65 and CW73).

3.4.4. Differences by color

The differences of color are evaluated maintaining fixed the texture and finish variables.

3.4.4.1. Acrylic cladding (SIP). In general, in all finishes and textures, *white* and *ivory* colors have better capacity to mitigate the UHI. They reach an average solar reflection index of 94% and 85% respectively.

For the *Fine travertine rulato* texture: White color-SIP01 reaches a temperature of 312 K and SRI of 97%, while the hottest alternative, *Fine travertine rulato-dark gray*-SIP08 reaches up to 342 K and SRI get off 37%. That is, the surface temperature difference is 30 K and the SRI difference is 60%.

For the *Rustic travertine rulato-ivory* texture-SIP10 is the coldest reaching surface temperature of 311 K and SRI of 99% while the hottest alternative, *Rustic travertine rulato-dark gray*-SIP16 reaches up to 342 K and SRI get off 38%. That is, the surface temperature difference is 31 K and the SRI difference is 61%.

For the *Fine llaneado-paris stone*-SIP19-shows the best thermal behavior (T_s = 309, SRI = 100%) while *Fine llaneado-dark gray*-SIP 24 shows the worse performance (T_s = 347, SRI = 29%). Comparing *Fine llaneado-paris stone*-SIP19 with *Fine llaneado-ivory*-SIP 18 (T_s = 333, SRI = 55%), it is observed that, even when the color difference is not significant, the *ivory* colored combined with *Fine llaneado* texture seems to have a strong impact over the thermal behavior of cladding.

For the *Rustic llaneado* and *Medium granitex* texture: *white* color shows the best behavior (SIP 25: T_s = 314, SRI = 94% and SIP 33: T_s = 312, SRI = 97.5%) and *dark gray* color is the worse (SIP 32: T_s = 345, SRI = 33%, SIP40: T_s = 343, SRI = 35%).

3.4.4.2. Concrete cladding (CW). In general, *white* and *ivory* colors have better capacity to mitigate the UHI. They reach an average solar reflection index of 87%, for both colors, in the most of finishes evaluated.

The differences of color are evaluated for the medium texture in diverse type of finish.

For the *Medium rulato textured-white*-CW41 reaches a temperature of 311.5 K and SRI of 98%, while the hottest alternative, *Medium rulato textured-dark gray*-CW48 reaches up to 340.5 K and SRI get off 41%. That is, the surface temperature difference is 29 K and the SRI difference is 57%.

For the *Medium travertine textured* finish: *ivory* color–CW50 is the coldest reaching surface temperature of 318 K and SRI of 86% while the hottest alternative, *terracotta* color-CW53 reaches up to 334 K and SRI get off 53%. That is, the surface temperature difference is 16 K and the SRI difference is 33%. Among the lightest color and the darkest-white and dark gray it can be observed a similar thermal performance. This result seems to indicate that the thermal behavior is commanded by the finish.

For *Salpic salpicrate* finish: *white* and *ivory* color-CW57, CW58 show the best thermal behavior (T_s = 315 K, SRI = 91%) while *dark gray* color-CW64 shows the worse performance (T_s = 341 K, SRI = 41%).

For *Ironed salpicrate* finish the thermal performance is similar to *Salpic salpicrate*: white color-CW65 is the coldest (T_s = 314 K, SRI = 94%) and *dark gray* color-CW72 is the hottest (T_s = 341 K, SRI = 40%).

In both cases-*Salpic salpicrate* and *Smooth salpicrate* finish the thermal behavior depends by the color

For *Medium granitex* finish: *white* color-CW73 shows the best thermal behavior (T_s = 314 K, SRI = 92%) and *green* color-CW79 shows the worse performance (T_s = 334.5 K, SRI = 53%). It is observed that in the Medium granitex-dark gray-CW80 color seems to have a good thermal performance. (T_s = 320.5 K, SRI = 80%). Again, this result seems to indicate that the thermal behavior is commanded by the finish.

3.5. Pedestrian pavements according to relieved in the city

In Fig. 7a there were drawn the thermal and optical properties of the materials most frequently detected in the urban area, setting the value of SRI in each case.

Among the most widespread pedestrian pavements, the *Smooth concrete/calcareous-single line straight-red*-P36 represents 30%. This pavement reaches a surface temperature of 340 K with an SRI of 41%. Its albedo is 0.53 and the emissivity of 0.90. The *Smooth concrete/calcareous-yellow* represents 25% in the city and is the more efficient. In its two forms: *single line straight*-P37 and *multiline straight*-P38, have temperatures of 339 K, with an SRI of 42%. Their albedos and emissivities are 0.54 and 0.90 respectively. The third material most used in the city is the *Rustic concrete/stone-boulder flat-gray*-P06 (18%). Its surface temperature is 338 K, with an SRI of 45%. Its albedo = 0.56 and emissivity = 0.90.

Finally, with 13% of frequency, the pedestrian pavement S*mooth concrete/calcareous-single line straight-black*-P35 was relieved with a rate of SRI = 28%, albedo = 0.42 and emissivity = 0.95, reaching a higher heating value 346.5 K.

Among the studied pavements, the alternatives with greater capacity to mitigate urban heat island are: *Smooth natural stone-mosaic flat-travertine*-P34, the *Smooth natural stone-mosaic flat-gray*-P25, the *Smooth concrete/stone-andalucía circular-gray/multicolor*-P13, and the *Rustic concrete-start flat-gray*-P18. These ones have higher percentages of solar reflectance index to 48% (Fig. 7a).

3.6. Tiles according to relieved in the city

The tiles used more frequently in the urban area of Mendoza are *Enamel clay-french-terracotta*-T03 and *Natural clay-colonial-terracotta*-T01. They have identical thermal behavior with the same SRI albedo and emissivity. (SRI = 64%, $\hat{a}$ = 0.64, ε = 0·90)· These tiles are in the group with better SRI.

It is true that black tiles show the worse thermal behavior (see T12 and T13 in Fig. 7b). Therefore, recently they are used in an intensive form in the urban areas. Then, it is important to remark that, *clay* tiles present better performance than *fiber-cement* tiles (i.e. T04-T13 in Table 2).

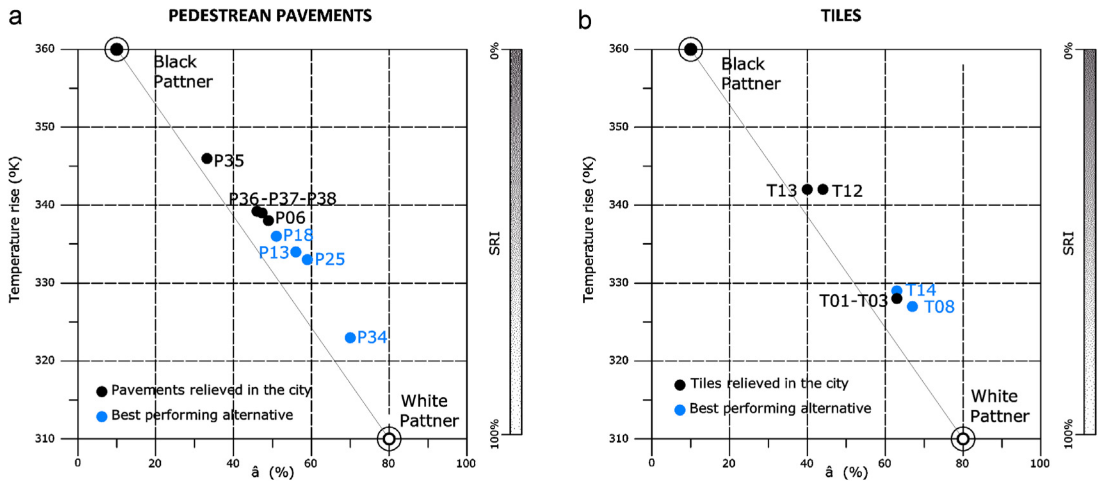

Fig. 7. Solar reflectance index. (a) SRI of pedestrian pavements, according superficial temperature (K) y albedo (%). (b) SRI of tiles, according superficial temperature (K) y albedo (%).

4. Conclusions

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.

In this context, the results of this work confirm the importance of classify the thermal behavior of materials available regionally for the resolution of the envelopes in order to transfer this information to the responsible of the habitat development. With the final goal to get in the medium term the urban sustainability.

Since SRI is an index set by ASTM E1980, it allows validating the results obtained locally with those already available in the academic world.

A comparative analysis of the optimization potential offered by each of the envelopes tested-pedestrian pavement, tiles and vertical claddings determines that: The 78% of the horizontal envelope-pedestrian pavements and tiles-shows a solar reflectance index – SRI lower than 50%. Its variability is 30% between the best and the worst behavior. For the case of the vertical claddings its variability is 70% (SRI 30–100%). If it is considered that, the horizontal urban envelopes present a critical condition related with solar exposition, and according to SRI values, it can see they offer lower possibilities for their thermal behavior improving. In the case of vertical claddings, although their solar exposition is lesser, the claddings evaluated present a wide range for manage their thermal behavior.

Much of *pedestrian pavements* present in the city, show reduced ability to mitigate the UHI, compared with other alternatives available in the local market. The most commonly used pavement in the city, S*mooth concrete/calcareous-red*-P36 has a reflectivity index of 41%, while the most efficient option (*Smooth natural stone-mosaic flat-travertine*-P34) has 75% proficient to reduce heat loads. This alternative is efficient from the thermal point of view however it has *smooth* texture and low resistance to high circulation. These features condition the massive use on sidewalks. The options that conciliate thermal and functional aspects are: *Smooth natural stone-mosaic flat-gray*-P25 and *Smooth concrete/stone-andalucía circular-gray/multicolor*-P13.

In general, as is expected, the better thermal behavior is linked to light colors for all shapes, compositions and finish. Dark colors, like black, show the best performance in the case of the *Rustic concrete-spider circular-black*-P02 (SRI 37%) and the worse in the case of the *Smooth concrete/calcareous-single line straight-black*-P35 (SRI 28%). Although the SRI values are low, its uses improve 30% the performance respect to most unfavorable condition. Regarding the roofing materials, *tiles*, the results demonstrate that thermal performance of tiles is the combined effect of: the composition and color. Clay compositions of light color shave a higher performance than fiber-cement composition. For example the *Natural clay-colonial-terracotta*-T01 shows a SRI of 64% while the *Natural fiber cement-colonial-terracotta*-T11 has a SRI of 48%. The same phenomenon is generally observed in dark colored tiles: the clay composition has a greater ability to diminish the surface temperatures in the city, compared with fiber-cement composition. Commonly, the surface temperature in the black color tiles is around 10 K greater than in terracotta color tiles. And their solar reflectance index – SRI is 20% lesser.

As exceptional case, it can be seen that among the black tiles, the tile *Matte fiber cement-colonial-black*-T15, has the better SRI (52.5%). And, between the fiber-cement tiles the *Natural fiber cement-french-gray*-T14 has the best SRI (63%). According with the new tendencies, the use of these materials could be an alternative for to solve the roof in a thermally efficient way.

Respect to the shape it was observed that, keeping fixed the color and finish, the colonial shape shows the best performance in terms of superficial temperature and SRI.

In regard to finishes, the natural and enameled materials seem to be thermally more efficient than the matte and aged materials.

Finally, the tiles used more frequently in the urban area of Mendoza – *Enamel clay-french-terracotta*-T03 and *Natural clay-colonial-terracotta*-T01 are in the group with better SRI. This proves that, the roofing materials traditionally selected in the city, are friendly with the local environment from the thermal point of view. Currently, this positive situation is threatened by the inclusion of new trends in the local architectural design that emphasize the use of dark colors.

Regarding the *vertical claddings*, from the assessment of their SRI behavior, it is observed the following trends:

In the range of SRI between 100% and 80% is found the 42.5% of acrylic claddings (SIP) and the 27.5% of concrete claddings (CW). This result shows the best ability of acrylic composition to mitigate the effects of UHI. In an intermediate range, between 60% and 40% are 40% of acrylic claddings and 70% of the concrete claddings. Finally, in the range below of 40% is found the 17.5% of acrylic claddings and the 2.5% of concrete claddings.

In the acrylic claddings the most important variable in the definition of their thermal behavior is the color meanwhile for the case of the concrete; it is the result of the combined effect of the texture and color. In the case of the acrylic claddings the color

selection among the different textures and finishes can improve their thermal behavior in 60% respect to the solar reflectance index and diminish their surface temperature around 30 K. Light and dark colors (*white* and dark *gray*) are little influenced by the texture and finish, while intermediate colors (ivory, light gray, paris stone, terracotta, green, ochre) have significative differences associated to these variables. The SRI varies between 20% and 40%.

In the case of concrete claddings, their SRI is on the intermediate range (60–40%) in the most of the cases. This performance indicates that the use of concrete claddings offers few possibilities to reduce the UHI.

At the same time, due to only the 2.5% of evaluated claddings have a low SRI range, the use of most of these claddings are not detrimental to the thermal functioning of the vertical urban envelopes.

Finally, the management of different variables (color and texture) has an impact on their thermal behavior that varies between 16 K and 30 K regarding its superficial temperature and 33–57% in terms of solar reflectance index.

In future steps, will be studied the thermal behavior of materials in the winter period. The aim is to assessment the resulting energy budget from the use of diverse strategies for improve the surface temperature of urban envelopes. With the final objective to mitigate the adverse effects of the city over the urban climate; reduce the consumption of fossil energy in the buildings and improve the thermal comfort in the urban space.

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