Assessment of the effectiveness of cool and green roofs for the mitigation of the Heat Island effect and for the improvement of thermal comfort in Nearly Zero Energy Building

Architectural Science Review, 2014
http://dx.doi.org/10.1080/00038628.2014.966050

Assessment of the effectiveness of cool and green roofs for the mitigation of the Heat Island effect and for the improvement of thermal comfort in Nearly Zero Energy Building

Q1

Elisa Di Giuseppe* and Marco D'Orazio

Department of Construction, Civil Engineering and Architecture, Università Politecnica delle Marche, Ancona, Italy

(*Received 28 May 2013; accepted 4 September 2014*)

The effectiveness of cool and green roofs to improve thermal comfort could be strongly dependent on the *U*-value of the roof itself and on the way it has been constructed (ventilated or unventilated, lightweight or massive, etc.). Recent strict limits on the *U*-values of building envelopes run the risk of reducing the effectiveness of cooling strategies in roofs which could be employed in warm and temperate climates to reduce surface temperatures and consequently to cool internal environment. In this paper, we experimentally analyse some roof systems (a high-albedo membrane and a green roof) compared to traditional ones in a Nearly Zero Energy Building, in order to provide new information concerning their effect on the internal comfort and the air temperatures of the surrounding environment. Experimental results confirm that, while the effectiveness of green and cool roofs for the mitigation of the Urban Heat Island effect is well established, the use of high-albedo materials on roofing systems with very low *U*-value is of little effectiveness for internal comfort. The green roof is distinguished by its passive cooling ability due to the evapotranspiration phenomena of the vegetation and the storage capacity of the substrate.

Keywords: cool roof; green roof; NZEB; thermal comfort; Heat Island

Introduction

In a building market that is moving towards Nearly Zero Energy Buildings (NZEBs), increasingly spreading coating materials are used with specific radiative properties, with the aim of reducing surface temperatures reached in the warmer seasons within buildings. In this way, it is believed to achieve a reduction in energy consumption for cooling and improve thermal comfort. However, the use of lightweight and strongly insulated envelopes even in hot and temperate climates is likely to rely entirely on the insulation, the function of containing the heat gains by solar radiation.

Q2

This role today, in countries with a warm climate, is mainly carried out by other strategies: envelopes with high thermal inertia (massive roofs and walls), ventilation systems (air gaps and discontinuous roof coverings) and materials with high albedo (buildings painted in light colours). These strategies risk to become less effective if used in strongly insulated envelopes.

Only few studies focus on the effectiveness of the use of materials with high albedo on overinsulated envelopes for the construction of NZEB.

D'Orazio, Di Perna, and Di Giuseppe (2010) have previously shown that an increase in roof insulation thickness decreases cooling potential due to traditional construction methods of roofs (ventilation, mass and radiative properties).

From the analysis of different real-scale roofing systems with various values of solar reflectance, Miller (2006) observed that the use of a metal cladding with high reflectance coupled to an undermantle ventilation reduced heat fluxes by 45%. However, only 15% of this percentage is due to the radiative properties of the material, while the remaining 30% is due to undermantle ventilation.

Zinzi and Agnoli (2011) analysed the performance of cool and green roofs on non-insulated ($U = 1.4$ W/m^2 K) and moderately insulated ($U = 0.6$ W/m^2 K) slabs with the help of Energy Plus software. They were able to obtain savings in consumption compared to traditional roof coverings by up to 13.9% in the case of non-insulated ones and only up to 7.8% in the case of moderately insulated ones.

By comparing two scale models of building in the absence and presence of insulation on the roof slab, increasing the albedo (from 0.30 to 0.70) Simpson and McPherson (1997) showed a reduction in total and peak hourly energy for cooling by only 5% for the insulated roof ($U = 0.19$ W/m^2 K) and by 28% for the non-insulated one.

Levinson, Akbari, and Reilly (2007), in a roof with thermal transmittance at around 0.25 W/m^2 K, analytically found that the energy savings for cooling, associated with the use of reflective materials in roof covering, is reduced

*Corresponding author. Emails: e.digiuseppe@univpm.it, elidigiu@gmail.com

by 85% compared to that obtained in a high transmittance roof. This trend gradually decreases exponentially with increasing insulation.

In addition, in locations where there is need for both heating during winter and cooling in summer, the use of material with high ~~SRI~~ could prove to be even counterproductive for the reduction of solar gains in the winter phase (Suehrcke, Peterson, and Selby 2008).

Nevertheless, high-albedo roofs (green and cool roofs) are recognized as fundamental strategy that dense urban areas can deploy on a large scale, at low cost, to mitigate the Urban Heat Island (UHI) effect (Gaffin et al. 2012). In fact, such materials reach modest temperatures when exposed to solar radiation; they reduce heat transfer to the adjacent air thereby contributing to the decrease in temperature on an urban scale.

The effectiveness of their use in climates with long summers and mild winters is supported by numerous studies.

Among them, Takebayashi and Moriyama (2007, 2009) and Takebayashi, Moriyama, and Sugihara (2012) investigated the performance of high reflectance roofs and green roofs, noting their ability to reduce the surrounding temperature with respect to a concrete roof by about 10°C.

Furthermore, recent studies confirm that both cool and green roofs can contribute considerably to the improvement of the urban environment (Santamouris 2012; Coutts et al. 2013; Kolokotsa, Santamouris, and Zerefos 2013; Saadatian et al. 2013).

Recently, Gago and Roldan (2013) realized a review on different strategies to mitigate adverse effects of UHI, highlighting that if the albedo coefficient of construction materials is increased, it is possible to achieve direct energy savings of 20–70%, while an effort should be made to systematize all current knowledge concerning the effects that greenery has on the urban microclimate.

Therefore, from the literature review, it is clear that the role of the radiative properties of building materials and that of green roofs is still to be investigated in detail, especially in relation to the technological evolution of the building envelope.

The research that we carried out thus sought to understand the influence of the type of roof covering (vegetation cover, high-albedo material, traditional surface coated in copper or brick) on roof's temperatures during warm and temperate season, also related to indoor thermal comfort and UHI effect.

Phases, materials and methods

The research was carried out in three successive steps:

- Laboratory measurements of optical properties (emissivity and solar absorption) of different roof covering materials: clay tiles, copper plates, zinc plates and a reflective sheathing.
- Insertion of some of the tested materials (clay tiles, copper plates and reflective sheathing) as roof covering of a building mock-up, also in comparison to a green covering.
- Assessment of the *in situ* albedo of the various covering and of their thermal performance.

Solar absorption was recorded by using spectrophotometers in visible light (Spectrum Model 554), infrared (Spectrum GX 1) and near-infrared (Spectrum One NTS) ranges. Emissivity was directly measured by using a pyrometer (Testo 830).

The *in situ* monitoring was carried out on a real-scale experimental building built in 2007 near Ancona (Italy, 2064 DD). The building is 8.20 m × 10.50 m, totalling 86.10 m^2 with a unique volume of around 250 m^3. The side walls were built with multi-layered insulating panels made of polyurethane resin ($U = 0.20$ W/m^2 K). Inside the envelope, a 30 cm air cavity was created with the help of 22 mm ~~OSB~~ panels in order to reduce the impact of solar radiation on the walls. The floor was insulated with 20 cm extruded polystyrene panels in order to make the building almost adiabatic.

The roof was divided into modules of the same width (1.50 m each) and same length of 6 m on the south slope and 3 m on the north slope, in order to obtain a similar size as that of traditional roofs (Figure 1). The common element among all the roof coverings is the insulation, which was made of two crossed layers of ~~EPS~~ panels with a total thickness of 12 cm ($U = 0.25$ W/m^2 K). The roof modules were well insulated (12 cm extruded polystyrene) on both sides to avoid any heat diffusion crosswise.

This research focused on four different roofs installed in the building: two ventilated clay tiles and copper roofs (respectively named LV6_A and MV6_A) originally installed in the building, a green roof (MNV_GR) and a roof with a reflective sheathing (MV6_RS) installed in a part of the existing roofs in 2011 (Figures 2 and 3).

The green roof installed had a culture substrate with medium–low thickness (15 cm) and low and evergreen vegetation of the "officinalis" type for which very little

Colour online, B/W in print

Figure 1. South view of the experimental building near Ancona (Italy).

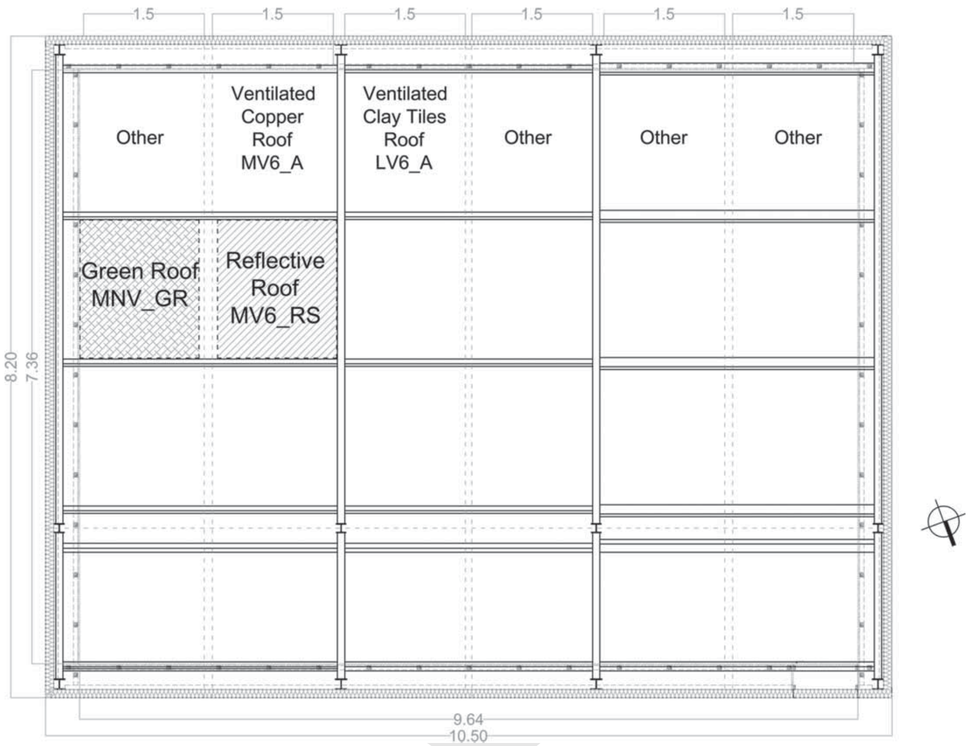

Figure 2. Plan of the experimental building with the schematic position of the original roofs installed in the building (ventilated clay tiles and copper roofs) and the high-albedo roofs (green roof and roof with a reflective covering) installed in 2011.

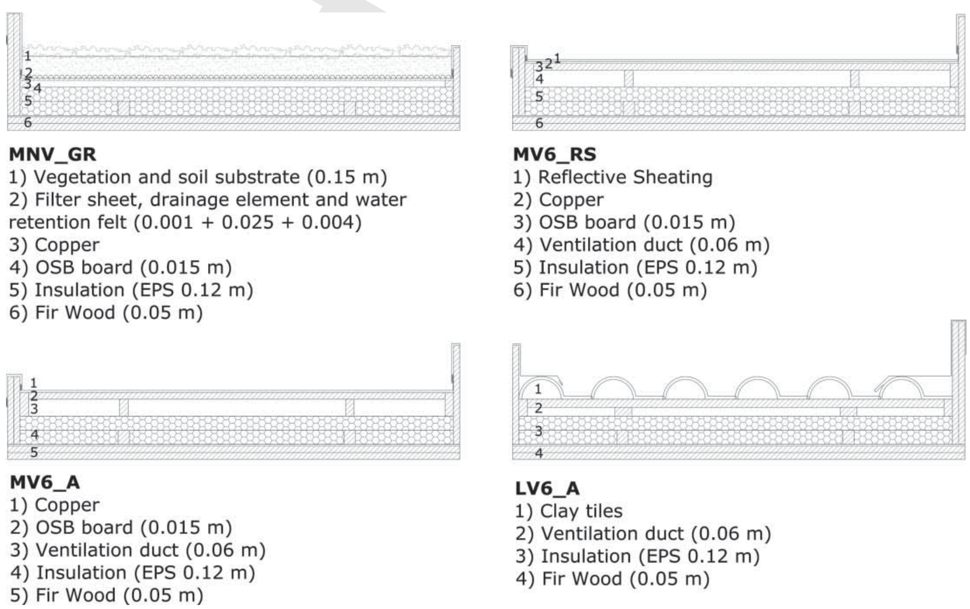

Figure 3. Stratigraphies of the four roofs installed in the experimental building: two ventilated clay tiles and copper roofs (LV6_A, MV6_A), a green roof (MNV_GR) and a roof with a reflective covering (MV6_RS).

maintenance is required. Table 1 shows the materials that constitute the roof.

An automatic drip irrigation system was installed on the green roof in the summer season, which automatically turned on at 6 a.m. every morning for one hour.

External weather conditions were recorded throughout the summer of 2011 by means of a 12-bit datalogger (Elog Lsi-Lastem) to which instruments were connected in order to measure global radiation (DPA 153 Lsi-Lastem), temperature and relative humidity of the air outside (DMA

Table 1. Thermophysical properties of the materials composing the green roof.

Layer	Thickness (m)	Material	Thermal conductivity (W/m K)	Density (kg/m^3)	Specific heat (J/kg K)
Vegetation and soil substrate	0.150	Lapillus, Compost	0.17 (dry) 0.33 (saturated)	582	1000
Filter sheet	0.001	Polypropylene	0.220	910	1900
Drainage, storage and ventilation element	0.002	Polyethylene	0.380	950	2300
Air (inside the drainage element)	0.023	Air	Thermal resistance = 0.16 W/m^2 K		
Retention felt	0.004	Polypropylene	0.220	910	1900
Roof covering	0.001	Copper	380	8900	382
OSB board	0.015	OSB	0.130	630	2200
Insulation	0.120	EPS	0.035	25	1470
Roof slab	0.050	Fir wood	0.120	550	2700

Colour online, B/W in print

Figure 4. Placement of the instrumentation for the albedo measurements on roofs composed of two coupled radiometers: one facing the sky to measure the incident global radiation and the other one towards the roof surface to detect the amount of reflected radiation.

572.1 Lsi-Lastem), speed and wind direction (DNA 021-024-027 Lsi-Lastem) and rainfall (DQA030 Lsi-Lastem). Thermal data on the roof stratigraphies were also observed in the same period by means of five 12-bit dataloggers (Elog Lsi-Lastem) connected to

- thermal resistances (PT100 Lsi-Lastem) for measuring temperatures within the different layers of the roof coverings (surface of the insulation, and surface of the covering, slab, ground and air cavities);
- probe for measuring temperature and moisture content in the planted roof soil (DISACC4825 Lsi-Lastem).

Temperature and relative humidity of the air (DMA 572.1 Lsi-Lastem) were also recorded inside the building.

The accuracy of the probes was ±0.15°C for PT100 thermal resistances, ±0.5% of mv for the anemometers, 5% for radiometric probes, ±0.1°C for internal air temperature probe and ±1.5% for internal ~~RH~~ probe, ±0.2°C for external air temperature probe and ±1.5% for external RH probe. The acquisition rate was set to 10 seconds, while the post-processing rate was set to 10 minutes. All the probes and measurement connections were calibrated beforehand, and the calibration results were noted in order to correct the values that were recorded.

In order to measure the albedo of roofs, the protocol developed by Sailor, Resh, and Segura (2006) was followed. A system of two coupled radiometers (DPA 153 Lsi-Lastem) was assembled: one facing the sky to measure the incident global radiation and the other one towards the roof surface to detect the amount of reflected radiation. The inclination of the instrumentation was then adjusted to 17°, the same as the roof's pitch (Figure 4). The albedo of the roof is represented by the ratio of total reflected radiation to incident electromagnetic radiation. Radiation measurements were carried out during four days of clear sky in the month of September. For the incident radiation, only the values which were greater than 100 W/m^2 were considered, to avoid the occurrence of errors and dispersions of results.

Results

Laboratory measurements of optical properties of different roof covering materials

The laboratory measurement of solar absorption and emissivity of different roof covering materials enabled the definition of the values listed in Table 2.

Table 2. Laboratory measurements of solar absorption and emissivity of different roof covering materials.

Material	Solar absorption	Emissivity
Reflective sheathing	*0.10*	*0.01*
Clay tile	*0.56*	*0.86*
Polished copper	*0.40*	*0.10*
Tarnished copper	*0.70*	*0.40*
Prepatinated zinc – dark pickling	0.70	0.50
Prepatinated zinc – clear pickling	0.30	0.30
Polished zinc	0.10	0.20

The reflective sheathing, clay tiles and polished copper, whose emissivity and solar absorption values are shown in italics in Table 2, are those used then to build roof coverings monitored on site. However, the copper, two months after installation in actual weather condition, reached a high degree of oxidation (tarnished copper).

Measured thermal emissivity was 0.10 for the reflective sheathing, 0.86 for clay tiles, 0.10 for polished copper and 0.40 for tarnished copper. Measured solar absorptivity of the reflective sheathing was 0.10, for clay tiles 0.56, while its value for copper might have varied from 0.40 to 0.70 depending on the oxidation degree of the material.

In situ *assessment of roofs albedo and their impact on the Heat Island effect*

The scatter plots in Figure 5 show the values of incident and reflected radiation, measured for the four analysed roofs MNV_GR, MV6_A, LV6_A and MV6_RS.

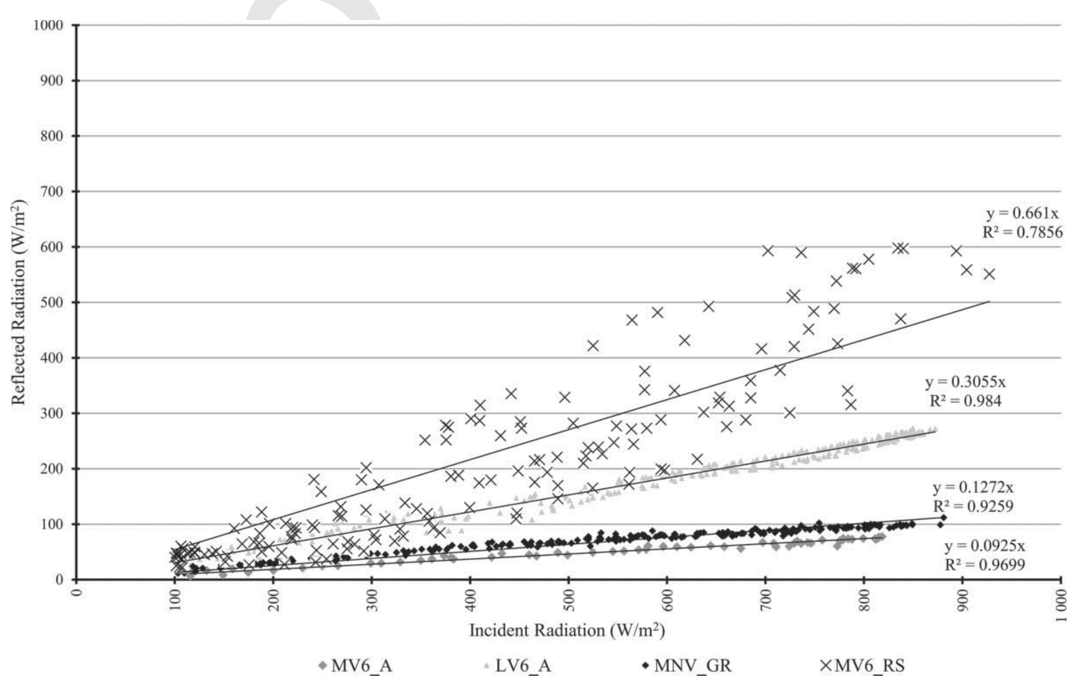

Figure 5. Roofs albedo, represented by the ratio of reflected radiation to incident radiation.

The lines that interpolate the points show a linear trend. The slope of these lines represents the value of albedo: 0.66 for the roof with reflective sheeting MV6_RS, 0.31 for the clay tile roof LV6_A, 0.13 for the green roof MNV_GR and 0.09 for the copper roof MV6_A. Even if for MV6_RS results are more scattered, the value of albedo for the reflective sheathing appears to be comparable with those proposed in the literature where the range varies between 0.65 and 0.80.

Concerning the green covering, the value of the resulting albedo is slightly lower than the other data found in the literature (Takebayashi and Moriyama 2007; Sailor 2008). However, it is important to consider that the passive cooling property of a green roof is not only due to its albedo, but also to a combined effect of soil insulation, evapotranspiration and radiative shading of the plant canopy.

The solar radiation flux coming into the green roof is a net contribution after solar reflection and absorption of the greenery, which depends on the Leaf Area Index, which is the ratio between the green area and the underneath soil area, and on the short-wave extinction coefficient (ks).

By using the exponential law developed by Palomo del Barrio (1998), we found (in percentage) that the greenery reflected 13 units and absorbed 56 units, calculated as residual term after the transmitted fraction of solar radiation. The solar radiation entering the system could then be estimated as 31% of the incident global solar radiation. The whole procedure is described in detail by D'Orazio, Di Perna, and Di Giuseppe (2012). This result is independent of the fact that the green roof was wet or dry, in agreement with others (Lazzarin, Castellotti, and Busato 2005).

Thermal performance of the roofs

Thermal analysis was carried out in the month of September 2011. The weather conditions in the month of September in Italy are usually highly variable, with sunny and warm days often followed by rainy cold days.

Figure 6 shows the main meteorological conditions monitored during a week in September (22–29 September 2011). The first day of the week is marked by high solar radiation (until 818.38 W/m^2) and air temperature (24.70°C), while the following days were cloudy and

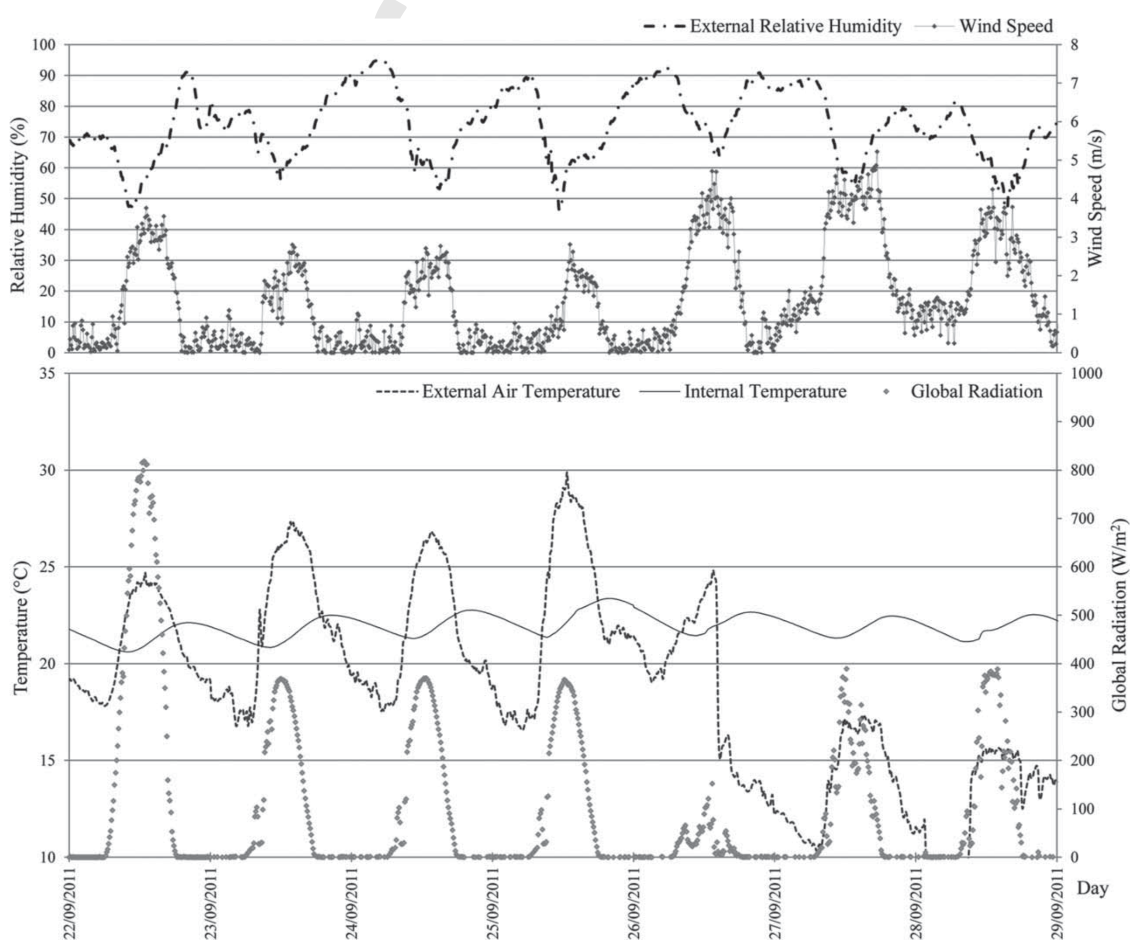

Figure 6. Meteorological conditions monitored during a week (22–29 September 2011).

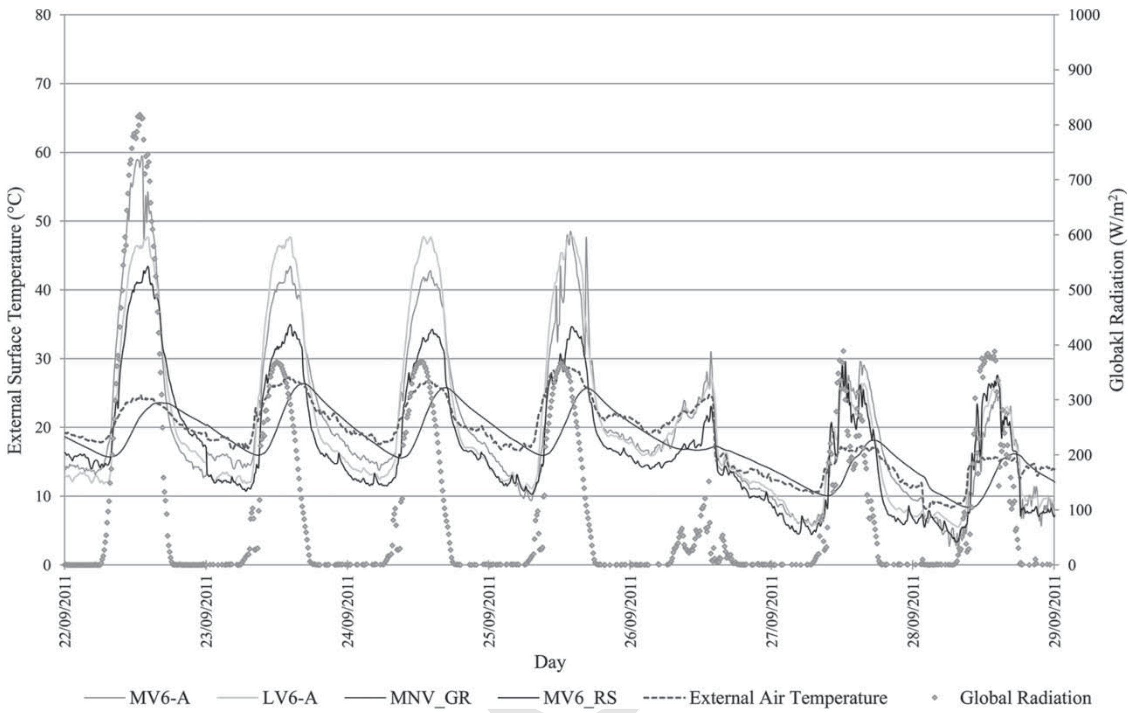

Figure 7. Roofs covering surface temperature trend (°C) with respect to the external air temperature and global radiation during a week (22–29 September 2011).

warm. Finally, air temperature decreased until very low values at the end of the week (15°C). During the week it has never rained.

Figure 7 shows the external surface temperatures of the roofs with respect to the external air temperature and total radiation during the week.

Figure 8 focuses on the first sunny and warm day (22 September). As it can be observed, the surface temperatures on the upper side of the substrate of the green roof (MNV_GR) during the day are actually lower compared to the external air temperature and reach a maximum of 23.60°C against an external temperature of 24.70°C. On the contrary, the covering temperatures of the other roofs are undoubtedly higher, with maximum temperature that reaches up to 59.50°C for the roof with copper covering (MV6_A) and goes down to 47.65°C for the ventilated clay tile roof (LV6_A) and 43.42°C for the reflective sheathing (MV6_RS).

The green roof surface temperature is also delayed in time compared to external air temperature because of the thermal inertia of the substrate. Water accumulation during the irrigation phase in the early morning (at 6 a.m.) also contributes to cool the roof.

Surface temperatures of the roofs decrease during the following days of the week according to the lowering of global solar radiation (Figure 7)

The cooling of the surface temperatures in relation to the different reflectance of the surface of the coverings is made evident in Figure 9, which shows the average and maximum surface temperatures of the surfaces as a function of the albedo on the day in question.

The only exception to the declining trend of the temperature values with the albedo is represented by the green roof, which, as seen above, has a performance strongly conditioned by the evapotranspiration phenomena of the leaves and the substrate.

Figure 10 shows temperatures on the soffit of the wooden slabs on the same day. It can be seen how the differences between the temperatures are rather low in terms of absolute value because of the high insulation of the slabs. However, the green roof (MNV_GR) is able to guarantee a lower internal surface temperature (until 21.98°C), which is also considerably attenuated and delayed in time compared to the other roofs (23.43°C for MV6_A, 22.70 for LV6_A and 22.91 for MV6_RS). In particular, the difference in the surface temperatures of the green roof was observed to be up to about 2°C compared to the temperature of the other ventilated roofs.

The temperature of the roof with the reflective sheathing (MV6_RS) is comparable to that of the other two ventilated roofs in the daytime phase, while it decreases during night-time hours, for phenomena of undercooling due to reduced emissivity of the reflective material.

Discussion

The experimental evaluation of the radiative properties of the different materials used as roof coverings has shown

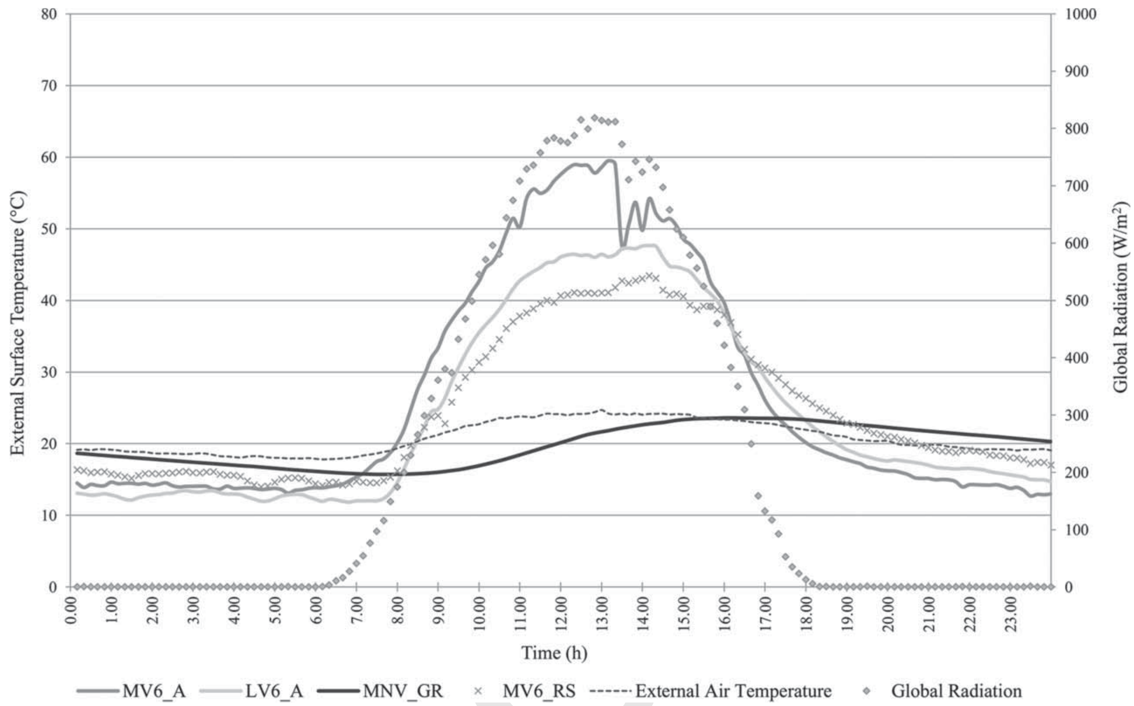

Figure 8. Roofs covering surface temperature trend (°C) with respect to the external air temperature and global radiation on a bright day (22 September 2011).

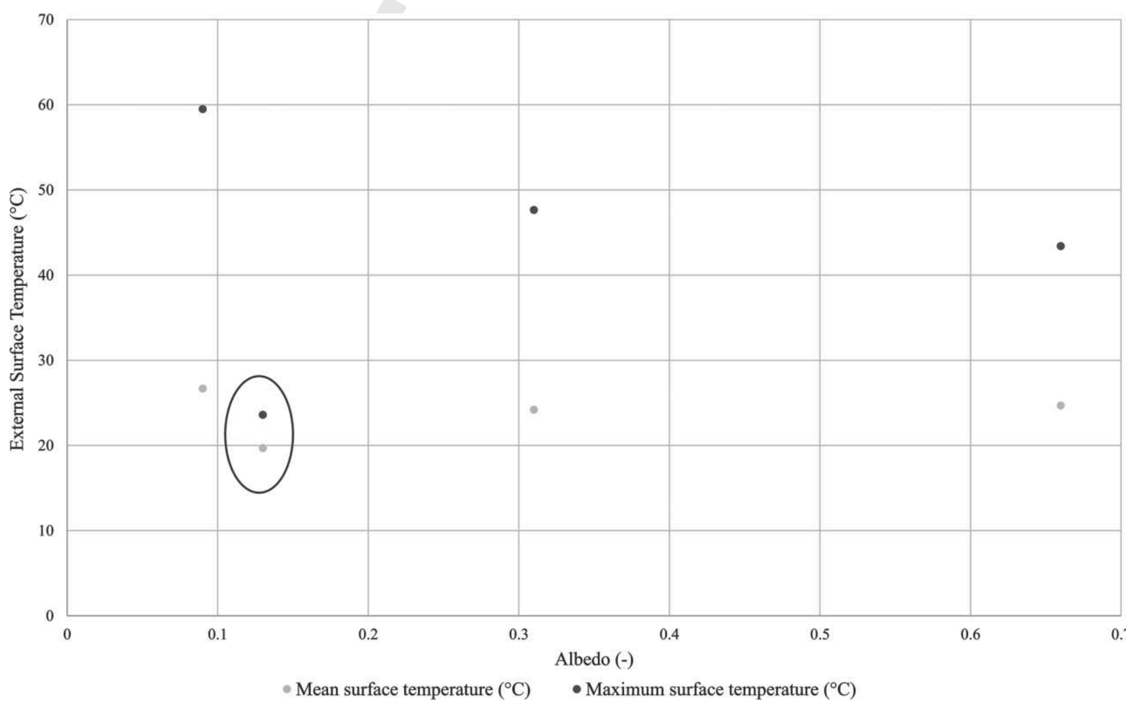

Figure 9. Average and maximum covering surface temperatures of the roofs as a function of the albedo on the day in question (22 September 2011).

that traditional materials (clay, copper and zinc) differ substantially due to the characteristics of their emissivity (high values for bricks and low for metallic materials). The reflective sheathing has the lower value, reaching an emissivity of 0.01 in factory conditions.

The absorption coefficient depends on the level of colour saturation of the material and on its ageing. Over time, the metallic materials tend to assume a surface patina that substantially alters their colour, making the saturation similar to that of bricks. The measurement of the

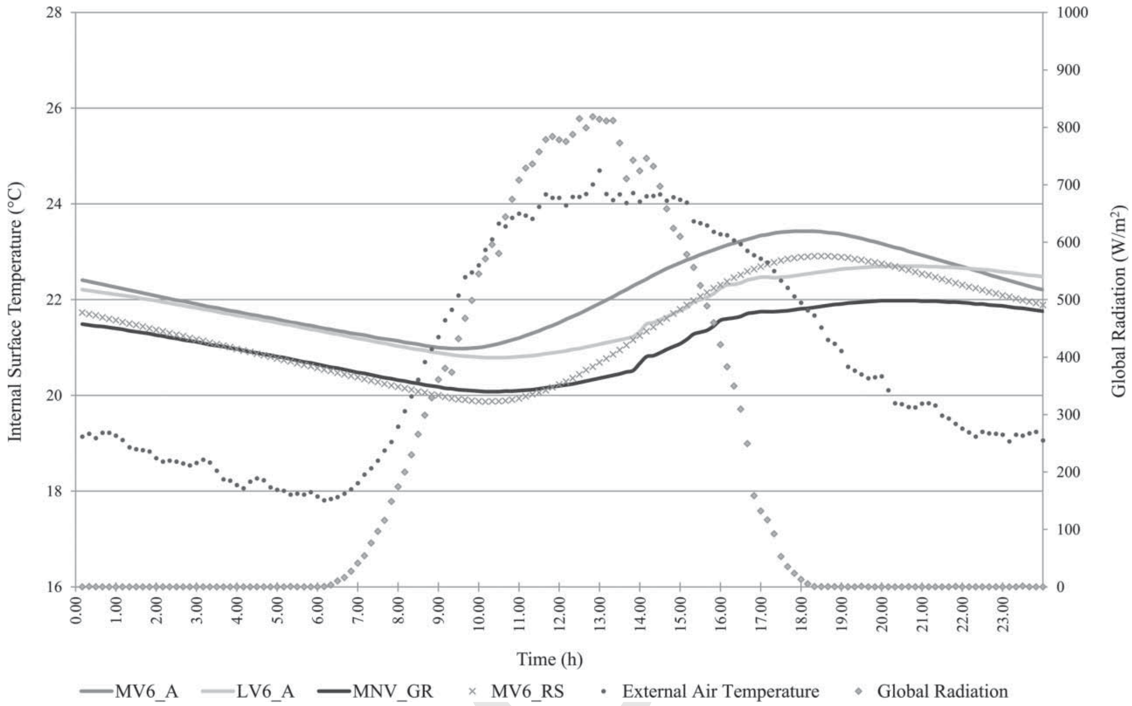

Figure 10. Roofs slab surface temperature trend (°C) on the day in question (22 September 2011).

absorption coefficient of the "new" material is therefore not indicative of the actual radiative properties of the material once put in place, as in the case of copper covering, and is thus subject to weathering, ageing and to variations in colour.

Preliminary measurements of the *in situ* albedo of roof covering materials show that green roof reaches a low value. In fact, the passive cooling property of a green roof is not only due to its albedo, but also due to a combined effect of soil insulation, evapotranspiration and radiative shading of the plant canopy. Experimental results confirm that the plant canopy reflects 13% of incident global solar radiation and absorbs 56%, so that the solar radiation entering the system can therefore be estimated as 31% of the incident global solar radiation.

The measured external surface temperatures of the two ventilated copper and clay tile roofs and of the reflective sheathing, together with the green roof, show a declining trend with an increase in the albedo of the covering. The green roof, for the reasons stated previously, represents the only exception.

Even if there are evident differences in the surface covering temperatures (a maximum of 59.50°C reached by the copper covering, against a maximum of 43.42°C for the reflective sheathing) during the warmer day analysed, as regards the internal slab surface temperatures, they do not turn out to be very different from each other because of the low transmittance of the systems.

Only the green roof guarantees internal slab temperatures, which are considerably attenuated (up to 2°C) and delayed in time compared to the other roofs.

Conclusion

The *in situ* monitoring of roofs with different covering materials (clay tiles, copper, vegetated substrate and reflective sheathing) confirmed a significant reduction in the external surface covering temperatures by increasing the albedo of the roofs. This result confirms that cool and green roof strategies could be effectively adopted for the mitigation of the Heat Island effect.

Nevertheless, the different external temperatures of the roofs become "flattened" internally, where the variances between the temperatures are rather low in terms of absolute value. In particular, the roof with reflective sheathing shows a performance similar to the other ventilated roofs. The use of high-albedo materials on roofing systems with very low U-value is then of little effectiveness for internal comfort. The green roof is distinguished by its passive cooling ability due to the evapotranspiration phenomena of the vegetation and the storage capacity of the substrate. It is able to guarantee a lower internal surface temperature (until about 2°C compared to other roofs), which is also considerably attenuated and delayed in time.

A lower temperature of the roof soffit reduces the mean radiant temperature of the attic (which depends on the internal temperature and on that of all the surfaces facing the room), impacting positively with environmental comfort during summer.

These results, relating to a building monitored in Italy, can be trusted in temperate climate, such as the northern Mediterranean, where the need for a significant R-value of the envelope in winter must be complemented by a reduction of solar gains in summer.

A remarkable thermal insulation is today an essential condition to achieve an NZEB, nevertheless strategies against the overheating in summer, such as green and cool roofs, still require further investigation in these kinds of buildings, taking into account the specific climatic conditions of local environments and also considering their economic feasibility.

Acknowledgements

We are grateful to Prof. C. Di Perna of Department of Industrial Engineering and Mathematical Sciences of Università Politecnica delle Marche for his assistance in laboratory and field measurement campaign.

References

Coutts, Andrew M., Edoardo Daly, Jason Beringer, and Nigel J. Tapper. 2013. "Assessing Practical Measures to Reduce Urban Heat: Green and Cool Roofs." *Building and Environment* 70: 266–276. doi:10.1016/j.buildenv.2013.08.021. http://linkinghub.elsevier.com/retrieve/pii/S0360132313002473

D'Orazio, M., C. Di Perna, and E. Di Giuseppe. 2010. "The Effects of Roof Covering on the Thermal Performance of Highly Insulated Roofs in Mediterranean Climates." *Energy and Buildings* 42 (10): 1619–1627. doi:doi:10.1016/j.enbuild.2010.04.004. http://linkinghub.elsevier.com/retrieve/pii/S0378778810001234

D'Orazio, M., C. Di Perna, and E. Di Giuseppe. 2012. "Green Roof Yearly Performance: A Case Study in a Highly Insulated Building under Temperate Climate." *Energy and Buildings* 55: 439–451. doi:10.1016/j.enbuild.2012.09.009. http://linkinghub.elsevier.com/retrieve/pii/S0378778812004598

Gaffin, S. R., M. Imhoff, C. Rosenzweig, R. Khanbilvardi, A. Pasqualini, A. Y. Y. Kong, D. Grillo, A. Freed, D. Hillel, and E. Hartung. 2012. "Bright Is the New Black – Multi-year Performance of High-Albedo Roofs in an Urban Climate." *Environmental Research Letters* 7 (1): 014029. doi:10.1088/1748-9326/7/1/014029. http://stacks.iop.org/1748-9326/7/i=1/a=014029?key=crossref.7068d4efc00266f68da7a6e24b5a3dee

Gago, E. J., and J. Roldan. 2013. "The City and Urban Heat Islands: A Review of Strategies to Mitigate Adverse Effects." *Renewable and Sustainable Energy Reviews* 25: 749–758. doi:10.1016/j.rser.2013.05.057. http://www.sciencedirect.com/science/article/pii/S1364032113003602

Kolokotsa, D., M. Santamouris, and S. C. Zerefos. 2013. "Green and Cool Roofs' Urban Heat Island Mitigation Potential in European Climates for Office Buildings under Free Floating Conditions." *Solar Energy* 95: 118–130. doi:10.1016/j.solener.2013.06.001. http://linkinghub.elsevier.com/retrieve/pii/S0038092X1300220X

Lazzarin, R. M., F. Castellotti, and F. Busato. 2005. "Experimental Measurements and Numerical Modelling of a Green Roof." *Energy and Buildings* 37 (12): 1260–1267. doi:10.1016/j.enbuild.2005.02.001. http://linkinghub.elsevier.com/retrieve/pii/S0378778805000514

Levinson, Ronnen, Hashem Akbari, and Joseph C. Reilly. 2007. "Cooler Tile-Roofed Buildings with Near-Infrared-Reflective Non-white Coatings." *Building and Environment* 42 (7): 2591–2605. doi:10.1016/j.buildenv.2006.06.005. http://linkinghub.elsevier.com/retrieve/pii/S036013230600151X

Miller, W. A. 2006. *The Effects of Infrared-Blocking Pigments and Deck Venting on Stone-Coated Metal Residential Roofs*. ORNL/TM. Vol. 9. Oak Ridge, TN. http://www.steel-depot.com/pdf/metro/airspace.pdf

Palomo del Barrio, E. 1998. "Analysis of the Green Roofs Cooling Potential in Buildings." *Energy and Buildings* 27 (97): 179–193. http://www.sciencedirect.com/science/article/pii/S0378778897000297

Saadatian, Omidreza, K. Sopian, E. Salleh, C. H. Lim, Safa Riffat, Elham Saadatian, Arash Toudeshki, and M. Y. Sulaiman. 2013. "A Review of Energy Aspects of Green Roofs." *Renewable and Sustainable Energy Reviews* 23: 155–168. doi:10.1016/j.rser.2013.02.022. http://linkinghub.elsevier.com/retrieve/pii/S136403211300124X

Sailor, D. 2008. "A Green Roof Model for Building Energy Simulation Programs." *Energy and Buildings* 40 (8): 1466–1478. doi:10.1016/j.enbuild.2008.02.001. http://linkinghub.elsevier.com/retrieve/pii/S0378778808000339

Sailor, David J., Kyle Resh, and Del Segura. 2006. "Field Measurement of Albedo for Limited Extent Test Surfaces." *Solar Energy* 80 (5): 589–599. doi:10.1016/j.solener.2005.03.012. http://linkinghub.elsevier.com/retrieve/pii/S0038092X05001507

Santamouris, M. 2012. "Cooling the Cities – a Review of Reflective and Green Roof Mitigation Technologies to Fight Heat Island and Improve Comfort in Urban Environments." *Solar Energy*. doi:10.1016/j.solener.2012.07.003. http://linkinghub.elsevier.com/retrieve/pii/S0038092X12002447

Simpson, J. R., and E. G. McPherson. 1997. "The Effects of Roof Albedo Modification on Cooling Loads of Scale Model Residences in Tucson, Arizona." *Energy and Buildings* 25 (2): 127–137. doi:10.1016/S0378-7788(96)01002-X. http://linkinghub.elsevier.com/retrieve/pii/S037877889601002X

Suehrcke, Harry, Eric L. Peterson, and Neville Selby. 2008. "Effect of Roof Solar Reflectance on the Building Heat Gain in a Hot Climate." *Energy and Buildings* 40 (12): 2224–2235. doi:10.1016/j.enbuild.2008.06.015. http://linkinghub.elsevier.com/retrieve/pii/S0378778808001485

Takebayashi, H., and M. Moriyama. 2007. "Surface Heat Budget on Green Roof and High Reflection Roof for Mitigation of Urban Heat Island." *Building and Environment* 42 (8): 2971–2979. doi:10.1016/j.buildenv.2006.06.017. http://linkinghub.elsevier.com/retrieve/pii/S0360132306001752

Takebayashi, H., and M. Moriyama. 2009. "Study on the Urban Heat Island Mitigation Effect Achieved by Converting to Grass-Covered Parking." *Solar Energy* 83 (8): 1211–1223. doi:10.1016/j.solener.2009.01.019. http://linkinghub.elsevier.com/retrieve/pii/S0038092X09000309

Takebayashi, H., M. Moriyama, and T. Sugihara. 2012. "Study on the Cool Roof Effect of Japanese Traditional Tiled Roof: Numerical Analysis of Solar Reflectance of Unevenness Tiled Surface and Heat Budget of Typical Tiled Roof System." *Energy and Buildings* 55: 77–84. doi:10.1016/j.enbuild.2011.09.023. http://linkinghub.elsevier.com/retrieve/pii/S0378778811004117

Zinzi, M., and S. Agnoli. 2011. "Cool and Green Roofs. An Energy and Comfort Comparison Between Passive Cooling and Mitigation Urban Heat Island Techniques for Residential Buildings in the Mediterranean Region." *Energy and Buildings*. doi:10.1016/j.enbuild.2011.09.024. http://linkinghub.elsevier.com/retrieve/pii/S0378778811004129