Cool Roofs: A Significant Step to Climate Improvement

Dr. sc. nat. Thomas Allmendinger, Glattbrugg

During the past 130 years, the atmosphere has warmed by an average of approx. 1.4°C (measured at the weather-stations). As the former US presidential candidate Al Gore has presented impressively in his book, being published in the year 2006 entitled *„An Inconvenient Truth"*, as well as in the respective film, that temperature change implied, among other effects, a worldwide melting of glaciers and of the polar ice caps. The nature, i.e. the flora and the fauna, has likewise been badly affected. In particular, the frequency and violence of storms has increased, that which might presumably be the result of an uneven warming-up of different regions thus leading to an increased formation of high and low pressure areas.

That increase in temperature is commonly linked to the increase of the carbon dioxide concentration in the air, in fact due to its – asserted – exclusive ability to absorb heat radiation. There is general talk of a »greenhouse effect« although the vault being part of each greenhouse is obviously absent and although the atmospheric carbon dioxide concentration is very low, i.e. about approx. 0.035 %. In particular and on the contrary, one should actually suppose that for the climate mainly the *near-ground layer of the atmosphere* is responsible, being warmed up in advance by the solar radiation via the Earth surface. Thereby, it is well evident that dark surfaces absorb more solar light than bright surfaces, converting it into heat, while the latter ones reflect at least one part of the solar energy back into the Space.

Within the scope of an own investigation[i], temperature measurements on differently painted *aluminium-plates* being perpendicularly exposed to solar light yielded that e.g. a black plate warms up 3.5 times faster than a white one (**diagram 1**). Likewise painted brick-plates warm up proportionally similarly but altogether faster since their heat capacity is smaller (**diagram 2**). Because the plates simultaneously emit heat – in fact all the more as they get hotter -, the temperature increase gradually slows down till a *constant limit value* is reached where the warming-up rate is equal to the emission rate. That limit value solely depends on the colour but not on the material. However, other influences may be important such as the agitation of the air, in particular winds and storms, inducing a cooling-down and thus a decrease of the temperature limit.

From such measurements, the so-called *albedo* (lat. »whiteness«) can be determined whereby a white surface serves as a reference whose value is assumed as 1.0, while the value of any other colour is lower implying a larger warming-up rate. If the intensity of the solar light is measured simultaneously by a solar-meter, the *solar reflexion-coefficient* can be determined. It corresponds roughly to the albedo, but for a white surface it is smaller than 1. Thus a large albedo and a large solar reflexion-coefficient involve a strong reflection of visible light and a low warming-up of the surface, respectively. As a consequence, the respective limit temperature will be low. The heating-up rate depends, on the one hand, on the surface coloration and therefore on the albedo, and, on the other hand, on the heat capacity of the material. Moreover, the heat conductivity may be relevant. Since aluminium exhibits a considerably higher heat capacity than brick, and all the more than wood, it warms up slower while it cools down also slower at night. Due to its high heat capacity, stonework behaves similarly.

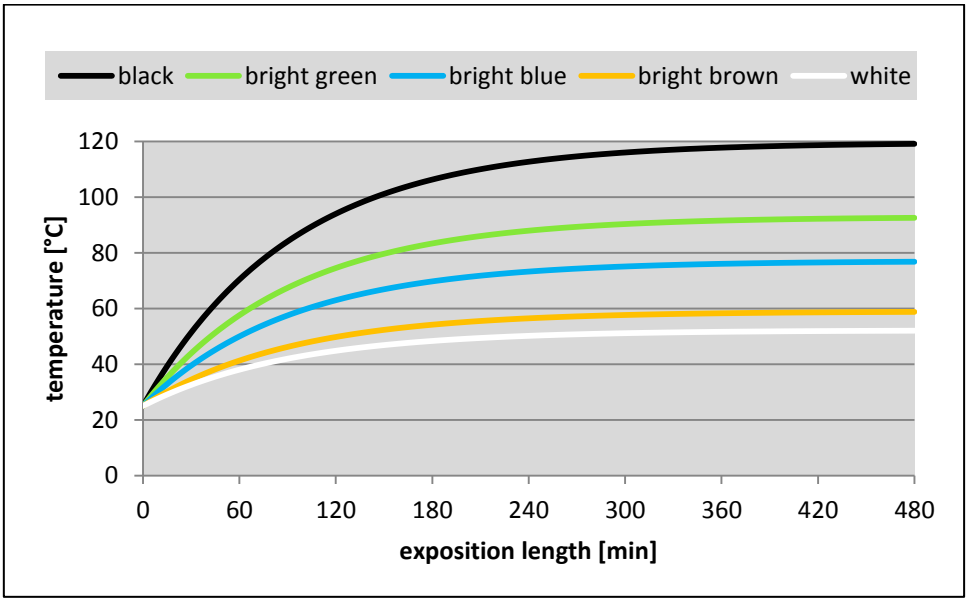


Diagram 1: Warming-up of aluminium-plates
at a solar irradiation intensity of 1000 Wm^{-2}
(plate-thickness 2 cm; with foil windows)

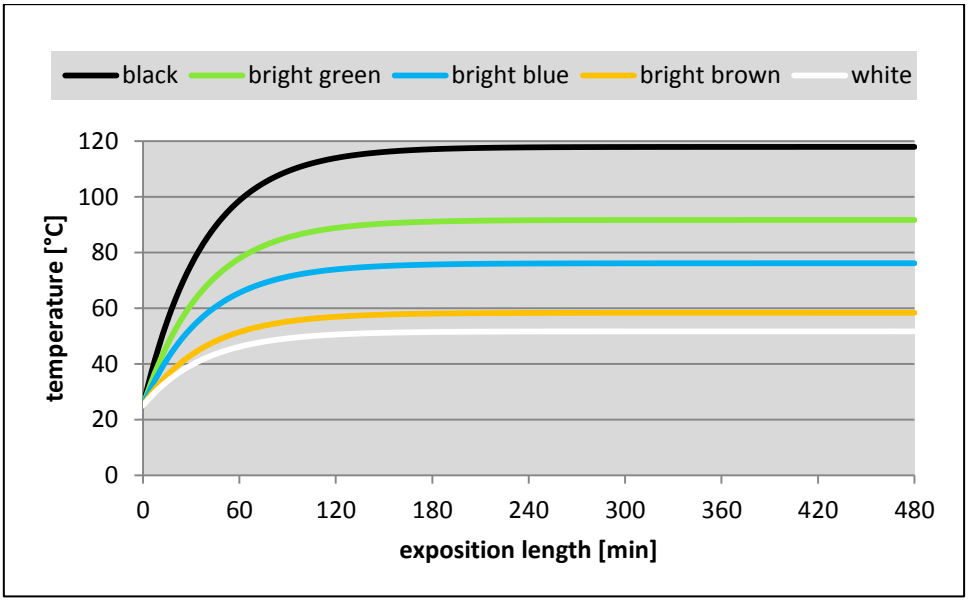
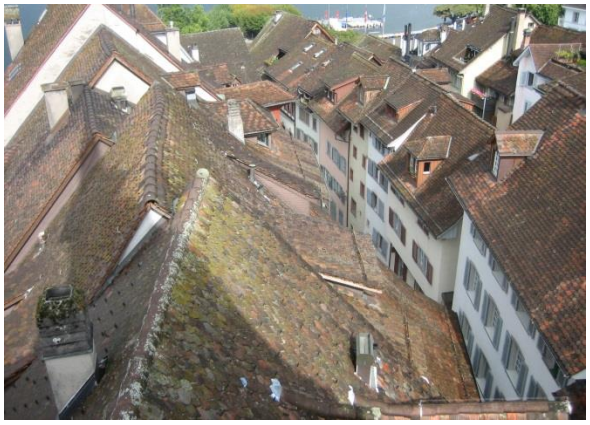


Diagram 2: Warming-up of aluminium-plates
at a solar irradiation intensity of 1000 Wm^{-2}
(plate-thickness 1,45 cm; with foil windows)

Since the beginning of the industrialization, and in particular since the last decades, the amount of buildings has massively increased, above all in cities, leading over all to a *darkening of the Earth surface*, accompanied by a local *surface enlargement* due to the roughening. Thereby, the *brick-roofs* act a considerable part since they are particularly exposed to the solar radiation. Besides, brick materials exhibit a relatively low heat capacity thus being warmed up comparatively rapidly **(diagram 2)**. In addition, many brick-tiles usually weather soon thereby getting darker **(picture 1)**. Since hitherto the albedo-effect has mostly been ignored, and since the appearance of roofs has usually not been emphasized, they often are in bad condition even at beautiful antique houses **(picture 2)**.

If the roofs of individual houses would be brightened up, preferably bright brown, certainly no relevant effect on the global climate would be expected. However, the individual *living comfort* would be improved in summer particularly when the roofs are not isolated, moreover it would be an *embellishment*. If complete settlements were equipped in such a way, even an improvement of the local *microclimate* could be expected, especially if accompanied by other measures such as the brightening of facades. The renovated historic buildings *Chillon Castle* at the Lake Geneva **(picture 3)** as well as the *Zunfthaus zur Zimmerleuten (guild house of the carpenters)* in Zurich **(picture 4)** provide the best proof that bright brown brick-tiles may well contribute to an embellishment of the townscape.

Picture 1: Aged roof with separate newish bricks



Picture 2: Historic district of Zug (Switzerland)

Picture 3: Chillon Castle at the Lake Geneva

Picture 4: Zunfthaus zur Zimmerleuten in Zurich

[i] Thomas Allmendinger (Feb. 2016): „The Solar-reflective Characterization of Building Materials", *http://allphyscon.ch → Albedo, Atmosphere Physics and Climate → Allmendinger Albedo 2015-09-17.pdf*