Expert Statement

on the Energy Saving Properties of Roof Paint "CoolDry"
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Ditoma GmbH
Dirk Weißenborn

DEKRA Industrial GmbH
Sustainability Management
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Index

EXPERT STATEMENT

Subject

The heating-up of buildings by solar radiation is a problem especially in areas with high irradiation, i.e. regions of low latitude like the Mediterranean, the Gulf Region, India, Australia and Central America. In these regions, houses are frequently built with flat roofs. In order to have a rainproof roof, bitumen is applied frequently. The dark colour of the bitumen absorbs irradiation to a large extent, heats up and thus increases the transfer of heat into the building, depending on the isolation of the roof. This additional thermal energy in the building will increase energy consumption by/due to air conditioning.

Using highly reflective roof-paint can reduce the heating up of the roof and thus reduce the transfer of thermal energy into the building. This will decrease energy consumption by/due to air conditioning.

DEKRA Industrial GmbH has been commissioned by Ditoma GmbH to evaluate the energy saving properties of their "CoolDry" roof-paint. The paint has been developed to reflect solar radiation and thus reduce the heating-up of buildings.

Theoretical background

The energy balance of a building is mainly characterised by the following parameters:

- *G*: global irradiance [W/m²]
- ρ_{solar}: reflection of sunlight
- U: isolation [W/m²K]
- Q: heat transfer [kWh/m²]
- $\varepsilon_h(T)$: hemispheric thermal emission rate
- T_o: temperature outside the building [K]
- T_i: temperature inside the building [K]
- Wind speed [m/s]
- Size of building, number and size of windows, number of floors, etc.

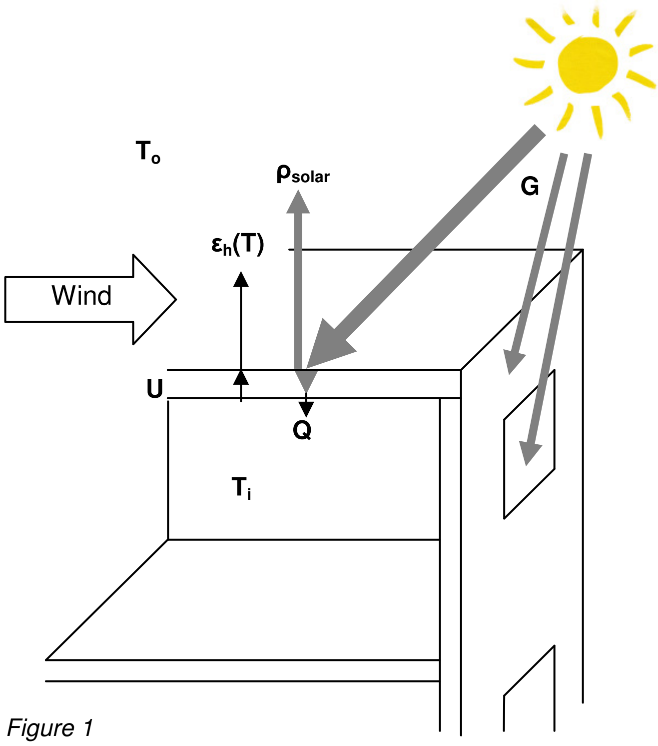

Figure 1

In order to obtain a desired temperature T_i inside the building, heating or cooling is frequently necessary.

Solar irradiance

Solar irradiance is the amount of energy coming from the sun and arriving on the earth's surface. Solar irradiance mainly depends on the geographical latitude of the geographical position in question. At low latitudes, the angle under which the sun appears on the sky at noon is steeper, therefore irradiance is more intense. Additionally, clouding and the seasons affect solar irradiance.

In Southern Germany, a maximum of 700 W/m² can be expected; in Malta, a maximum of 1000 W/m².

The intensity of sunlight irradiance also depends on the wavelength λ (see figure 2). The red graph depicts the wavelength range of sunlight, according to DIN EN 410. Visual light has a wavelength range of 0,38 µm to 0,78 µm. Radiation of a wavelength of between 0,78 µm and 1000 µm is described as infrared light.

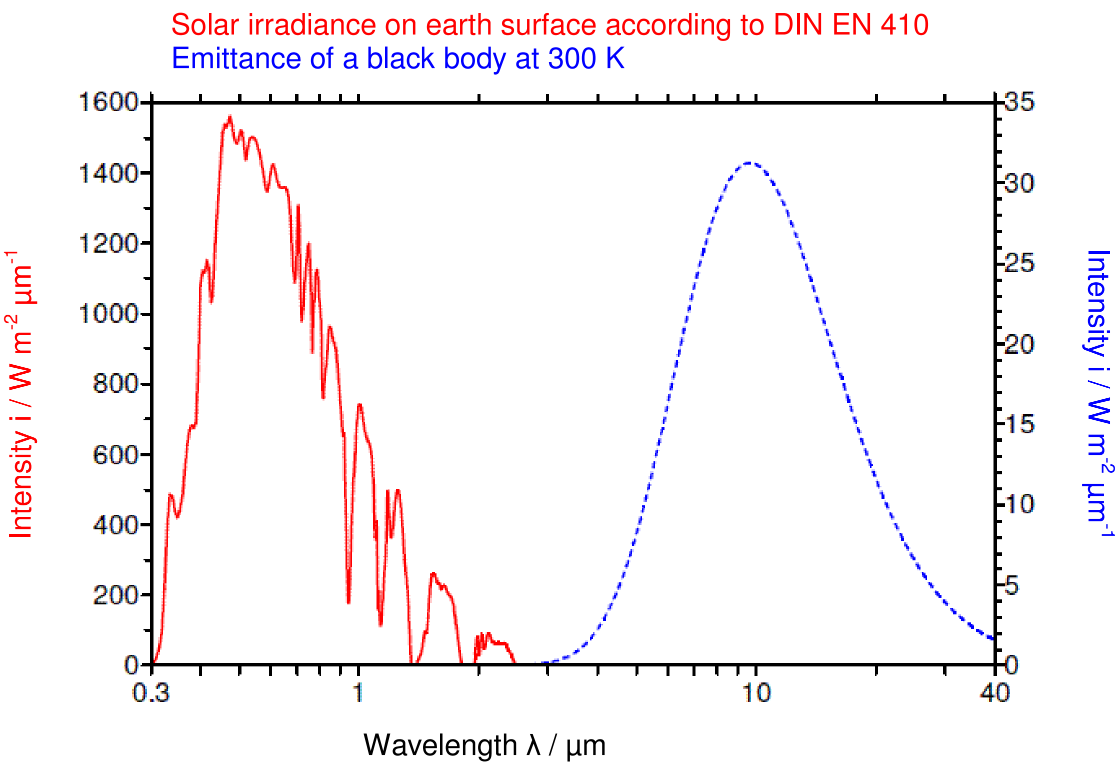

Figure 2

Reflection of sunlight

Depending on the surface, irradiance is reflected to a certain degree. White surfaces reflect a large amount of irradiance, black surfaces reflect a very small amount. Coloured surfaces only reflect light of a specific wavelength-range.

Reflection can be measured using spectrometers. Both irradiance and reflected radiation is quantified with the unit W/m^2. Therefore, reflection is quantified with the unit [1] (W/m^2 / W/m^2).

Emission of infrared radiation

Depending on the surface, a certain amount of infrared radiation is emitted. The emission depends mainly on the temperature of the surface. Hot surfaces emit parts of their thermal energy as infrared radiation. In doing so, the surface is cooling down gradually.

The radiance M of such a hot surface is measured in W/m^2. In order to obtain the emissivity ε, the radiance M is divided by the specific radiance M^o of a standard black body as defined by the “Stefan-Boltzmann-law”.

Therefore, emissivity ε is quantified with he unit [1].

Effect of wind on the emission of infrared radiation

The convective heat transfer coefficient describes a material’s ability to emit energy from the surface. This coefficient does not only depend on the material but also on the speed of the surrounding air.

High wind will remove warm air from the surface and bring cooler air that can absorb energy from the surface more easily.

The convective heat transfer coefficient has the unit [W/m^2K].

Transfer of heat into the building

Thermal energy on top of a surface will transfer into the material. The capacity of transferring thermal energy is material specific. Metal has a large capacity of transferring heat; air has a low capacity to do so. Therefore, isolation materials usually consist of materials that are porous and contain a high amount of air with low circulation inside the material.

The isolation capacity of a material is characterised by the U-value and the unit is [W/m^2K].

Architectonic features

The transfer of heat into the building does not only depend on the roof, but also on material and thickness of the walls, on number and size of windows, on shape, size and orientation of the building. As no specific building was defined, these aspects were excluded.

Determination of solar reflection

Approach

Ditoma GmbH prepared seven samples. Selected substrates included

- Concrete
- Concrete, covered with bitumen
- Metal (grey)

Four samples received a coating with "CoolDry" paint so that opacity was achieved. Of these four samples, three samples were coated with "CoolDry" white paint, one sample was coated with "CoolDry" beige paint. Three more samples were uncoated.

The samples were sent to a laboratory which carried out the following measurements:

- Spectral directional-hemispheric reflectance R_{gh} for a wavelength range of 0.25 µm to 35 µm, using an integrating sphere (also known as an Ulbricht sphere).
- Reflection of a wavelength range of 0.25 µm to 2.5 µm was detected by a Perkin Elmer Lambda 950 spectrometer.
- Emission of a wavelength range of 1.4 µm to 35 µm was detected by a Bruker Vertex 70v FTIR spectrometer.

Solar absorption α(solar) and solar reflection ρ(solar) were calculated by the laboratory according to DIN EN 410 and ISO 9050 respectively.

Directional emissivity $\varepsilon(\lambda)$ was calculated from R_{gh} by the laboratory. Total emissivity $\varepsilon(T)$ was calculated by the integration of the wavelength range of 1.4 µm to 35 µm using the Planck equation.

Hemispheric emissivity $\varepsilon_h(T)$ was calculated from $\varepsilon(T)$ by the laboratory according to DIN EN 12898 and ASTM E1585-93 respectively.

Solar Reflectance Index SRI was calculated from ρ(solar) and $\varepsilon_h(T=300K)$ according to ASTM E1980-01 by the laboratory.

Results

Following values were calculated from the measurements:

ρ(solar)	uncoated	CoolDry white	CoolDry beige
Concrete	0.26	0.79	0.72
Bitumen	0.05	0.78	
Metal	0.26	0.81	

SRI	uncoated	CoolDry white	CoolDry beige
Concrete	26	99	88
Bitumen	-3	98	
Metal	26	102	

Table 1

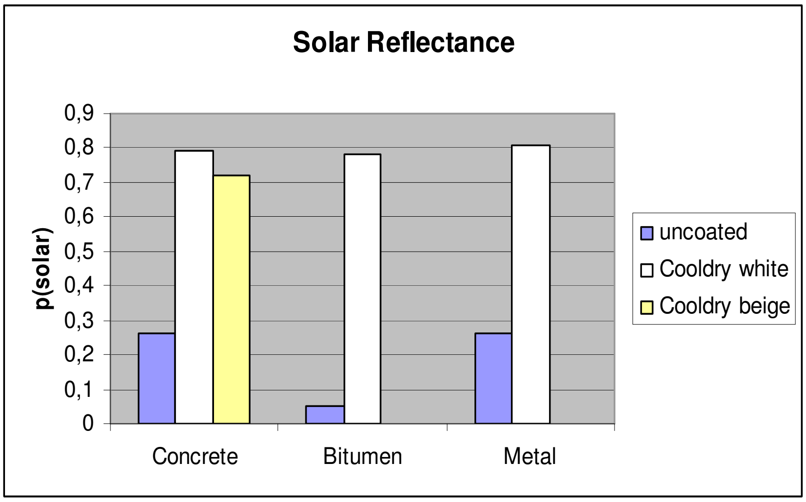

Figure 3

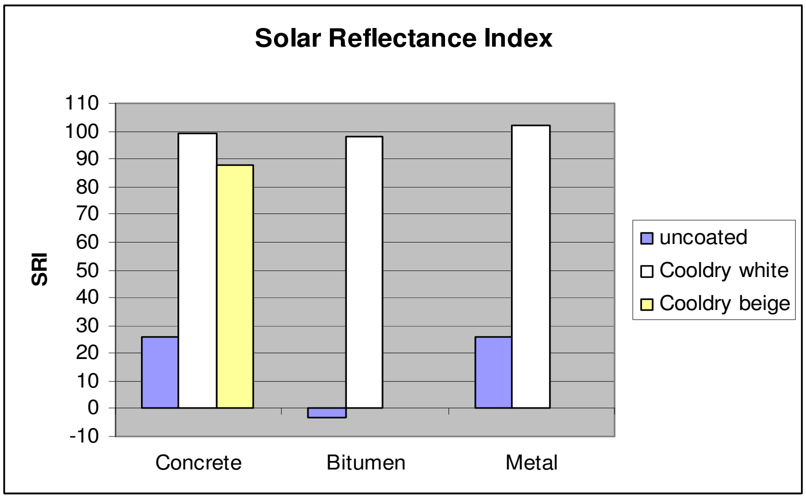

Figure 4

Determination of heat transfer via roof

Approach

In order to determine the input of thermal energy via the roof, several scenarios have been considered.

The product “CoolDry” has been developed for buildings in regions with high irradiance. Since it has already been applied to roofs in Malta, climate data from Malta (Luga/Qrendi data according to METEONORM Version 6.1.0.12) for the month of July has been used for all scenarios. Energy transfer was summarised for 31 days.

As no specific data on the building(s) have been pre-defined by *Ditoma GmbH*, six different scenarios for roof materials were calculated by the laboratory. Scenarios were chosen according to the roof types that are frequently used in Mediterranean countries. Isolation values for each material (U-values) were calculated with “EnEV-PRO 2009 / Wohnbau [6.0.4.0]”. Materials and U-values are displayed in table 2.

	U-value (W/m²K)	**ρ(solar)** uncoated	**ρ(solar)** Cooldry white
Concrete (no isolation)	4,13	0,26	0,79
Concrete (40mm iso)	0,88	0,26	0,79
Bitumen on concrete (no iso)	4,13	0,05	0,78
Bitumen on concrete (40 mm iso)	0,88	0,05	0,78
Metal (no iso)	7,14	0,26	0,81
Metal (40 mm iso)	0,97	0,26	0,81

Table 2

Heat transfer also depends on wind speed. Therefore, three different wind speeds were considered with their convective heat transfer coefficients (see table 3):

	convective heat transfer coeffcient [W/m²K]
Low wind speed	5
Mid wind speed	12
High wind speed	30

Table 3

As heat transfer through the roof also depends on the temperature inside, values were calculated for room temperatures of 20 °C and 25 °C.

All scenarios were calculated by the laboratory.

Results

All data is shown in the table in annex 1.

We see that coating with roof paint “CoolDry” has a remarkable effect on the heat transfer through the roof. The amount of heat transferred was reduced by coating between 68 % (concrete, 40 mm isolation, low wind) and 77 % (bitumen on concrete, high wind, no isolation as well as 40 mm isolation). Largest reductions in absolute numbers were calculated for “metal, no isolation, low wind (65,0 W/m²K)” and for “metal, 40 mm isolation, low wind (65,0 W/m²K)”. These equal a 74 % reduction in heat transfer.

Wind has a remarkable effect on heat transfer. The amount of heat transferred was reduced between 53 % (metal, no isolation) and 64 % (bitumen on concrete, 40 mm isolation) when considering high wind instead of low wind.

Roof material also has an effect on heat transfer. The isolation effect of a material is characterised by the U-value. While metal and concrete roof materials including a 40 mm isolation do not differ much in heat transfer (< 10 %), a concrete roof will transfer 46 % less of heat compared to a metal roof (high wind).

We see that indoor temperature T_i has little effect on the heat transfer through the roof (less than 1 %).

Figure 5 shows heat transfer for 4 scenarios (all values with mid wind).

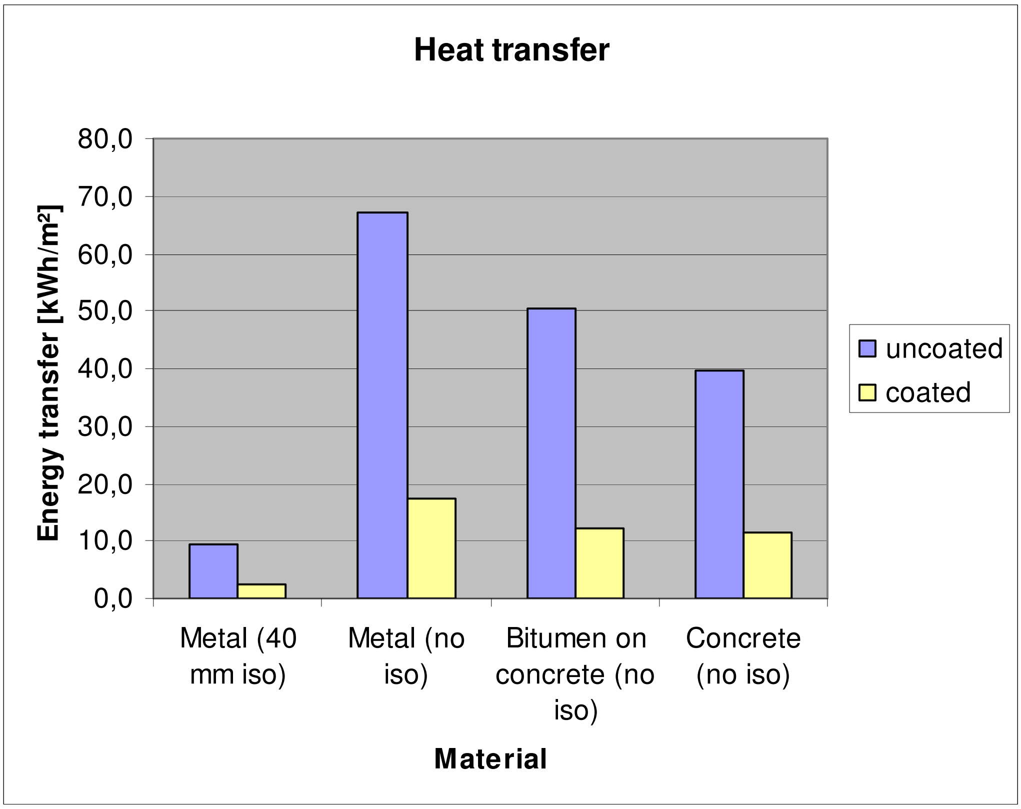

Figure 5

We see that heat transfer through the roof can be reduced significantly for all samples by applying a coating of “CoolDry”. We also see that 40 mm isolation reduced heat transfer to an even larger extent (metal roof, mid wind). The biggest reduction can be achieved by combining isolation and coating.

Conclusion

Samples covered with “CoolDry” paint showed a significant increase in solar reflectance compared to the uncoated substrates.

This effect resulted in a lower heat transfer through the roof. The energy transfer through the roof also depends on wind and on the roof material.

Therefore, buildings with concrete, bitumen or metal roofs that have been coated with “CoolDry” paint will heat up to a lesser extent than the same buildings with an uncoated roof.

Final Statement

This expert statement has been prepared to the best of our knowledge and belief.

Stuttgart, 29.09.2010

i.A.

Jochen Dettke

Project Management

i.A.

Michael Heinrich

Expert Energy Efficiency

ANNEX 1: SCENARIOS FOR HEAT TRANSFER

Roof Material	Wind	T_{innen} [°C]	Q_{dT} [kWh/m²]	$Q_{uncoated}$ [kWh/m²]	Q_{coated} [kWh/m²]	$Q_{uncoated} - Q_{coated}$ [kWh/m²]
Bitumen on concrete (40 mm iso)	low wind	20	3,8	16,4	4,2	12,2
Bitumen on concrete (40 mm iso)	medium wind	20	3,9	11,0	2,6	8,3
Bitumen on concrete (40 mm iso)	high wind	20	4,0	5,8	1,4	4,4
Bitumen on concrete (40 mm iso)	low wind	25	0,7	16,3	4,2	12,2
Bitumen on concrete (40 mm iso)	medium wind	25	0,7	11,0	2,6	8,3
Bitumen on concrete (40 mm iso)	high wind	25	0,7	5,8	1,4	4,4
Bitumen on concrete (no iso)	low wind	20	15,4	70,9	17,4	53,5
Bitumen on concrete (no iso)	medium wind	20	17,7	50,7	12,1	38,6
Bitumen on concrete (no iso)	high wind	20	20,0	28,9	6,7	22,1
Bitumen on concrete (no iso)	low wind	25	2,7	70,5	17,3	53,2
Bitumen on concrete (no iso)	medium wind	25	3,1	50,5	12,1	38,5
Bitumen on concrete (no iso)	high wind	25	3,4	28,8	6,7	22,1
Concrete (40 mm iso)	low wind	20	3,8	13,1	4,2	8,9
Concrete (40 mm iso)	medium wind	20	3,9	8,6	2,6	6,0
Concrete (40 mm iso)	high wind	20	4,0	4,5	1,4	3,2
Concrete (40 mm iso)	low wind	25	0,7	13,1	4,2	8,9
Concrete (40 mm iso)	medium wind	25	0,7	8,6	2,6	6,0
Concrete (40 mm iso)	high wind	25	0,7	4,5	1,4	3,2
Concrete (no iso)	low wind	20	15,4	56,2	16,6	39,5
Concrete (no iso)	medium wind	20	17,7	39,8	11,5	28,3
Concrete (no iso)	high wind	20	20,0	22,6	6,4	16,1

Concrete (no iso)	low wind	25	2,7	55,9	16,5	39,3
Concrete (no iso)	medium wind	25	3,1	39,7	11,5	28,2
Concrete (no iso)	high wind	25	3,4	22,5	6,4	16,1
Metal (40 mm iso)	low wind	20	4,2	14,4	4,0	10,4
Metal (40 mm iso)	medium wind	20	4,3	9,5	2,5	7,0
Metal (40 mm iso)	high wind	20	4,4	5,0	1,3	3,7
Metal (40 mm iso)	low wind	25	0,7	14,4	4,0	10,4
Metal (40 mm iso)	medium wind	25	0,7	9,5	2,5	7,0
Metal (40 mm iso)	high wind	25	0,8	5,0	1,3	3,7
Metal (no iso)	low wind	20	23,6	88,9	23,4	65,5
Metal (no iso)	medium wind	20	29,6	67,4	17,6	49,8
Metal (no iso)	high wind	20	36,6	41,4	10,7	30,7
Metal (no iso)	low wind	25	4,1	88,3	23,3	65,0
Metal (no iso)	medium wind	25	5,1	67,2	17,5	49,7
Metal (no iso)	high wind	25	6,3	41,4	10,7	30,7