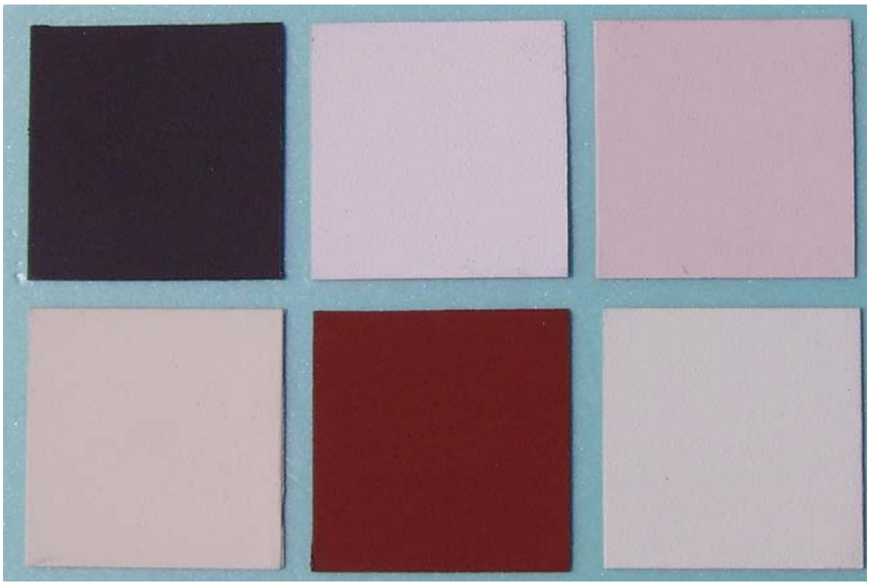

# EVALUATION OF THE OPTICAL PROPERTIES AND ESTIMATION OF THE COOLING LOAD SAVING POTENTIAL FROM THE USE OF SIX COATING SAMPLES

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# 1. INTRODUCTION

This report presents the results of the evaluation of the optical properties of six coating samples submitted for testing by ABOLIN exclusive distributor of Bioni CS GmbHas as well as the simulation results for the estimation of the cooling energy saving potential from the use of these coatings on the envelope of a residential building. This study includes:

- measurement of the spectral reflectance of the samples
- calculation of their solar reflectance,
- measurement of their infrared emittance,
- a simulation study for the estimation of cooling load savings from the application of the tested coatings on the envelope of a residential building

This study was carried out by the Group Buildings and Environmental Studies of the University of Athens, Physics Department, Section of Applied Physics.

# 2. EXPERIMENTAL ASSESEEMENT AND RESULTS

The six coatings studied are described in Table 1. For the measurements, the coatings were applied on aluminum plates of the following dimensions: 8cm (w) x 8cm (l) and of 1mm thickness. Surface was coated with a thickness of approximately 0,15-0,3mm.

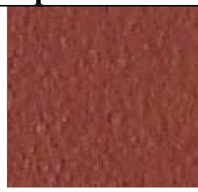
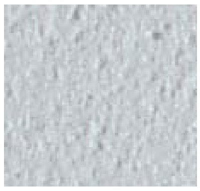
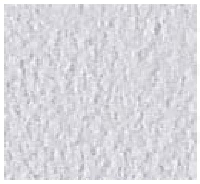
| i | Coating code | Color | Sample |
|---|---|---|---|
| 1 | bioni roof 102 | brown |  |
| 2 | perform flora 22 | light green |  |
| 3 | perform terra 20 | light pink |  |
| 4 | bioni perform sol 02 | light beige |  |
| 5 | perform white | white |  |
| 6 | bioni roof 104 | black |  |

*Table 1. Description of the tested coatings*

## 2.1 Measurement of the spectral reflectance

The spectral reflectance of the samples was measured in the range of 300-2500nm. The instrument used is a UV/VIS/NIR (Varian Carry 5000) fitted with a 150mm diameter, integrating sphere (Labsphere DRA 2500) that collects both specular and diffuse radiation. The reference standard reflectance material used for the measurement was a PTFE plate (Labsphere). The measurements were performed according to the ASTM E903-96 standard: Standard Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres. The results from the spectrophotometric measurements are shown in Figures 1-6.

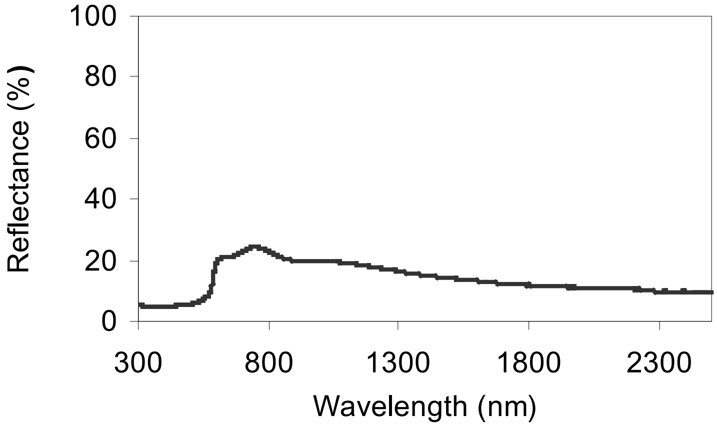



*Figure 1: The spectral reflectance of bioni roof 102*

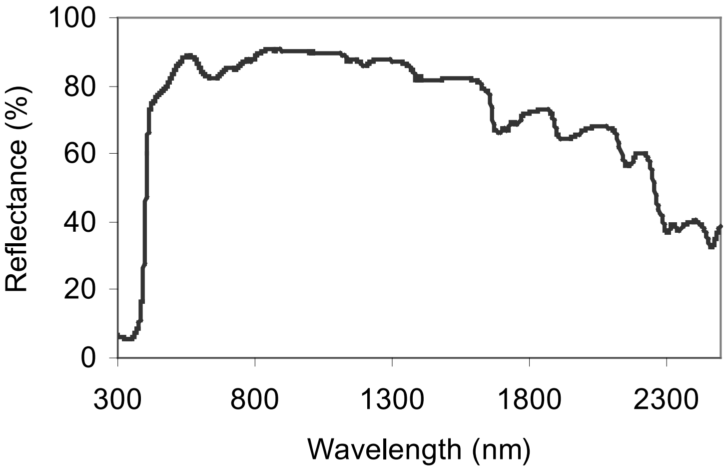



*Figure 2: The spectral reflectance of perform flora 22*

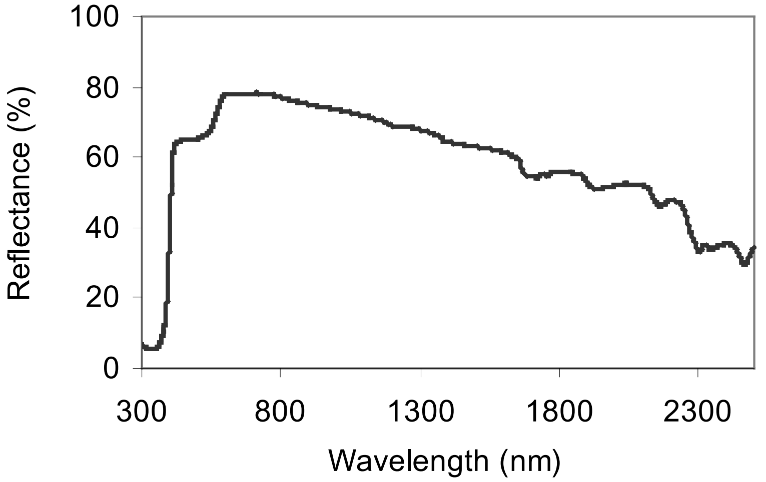



*Figure 3: The spectral reflectance of perform terra 20*

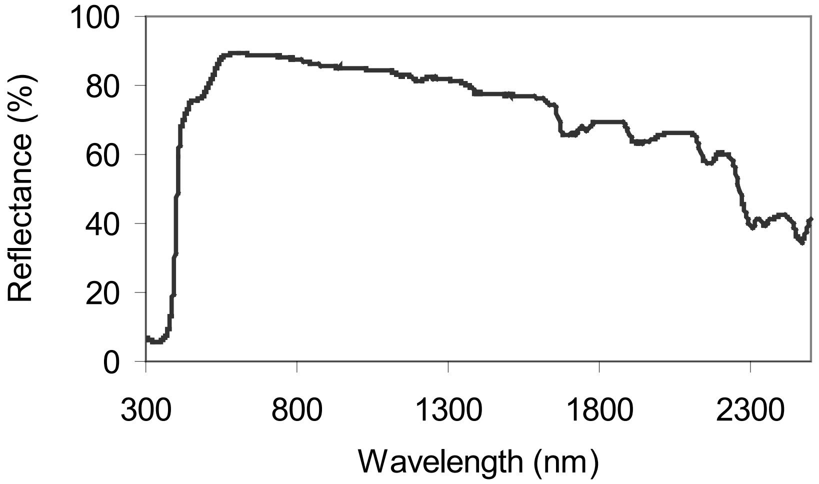



*Figure 4: The spectral reflectance of bioni perform sol 02*

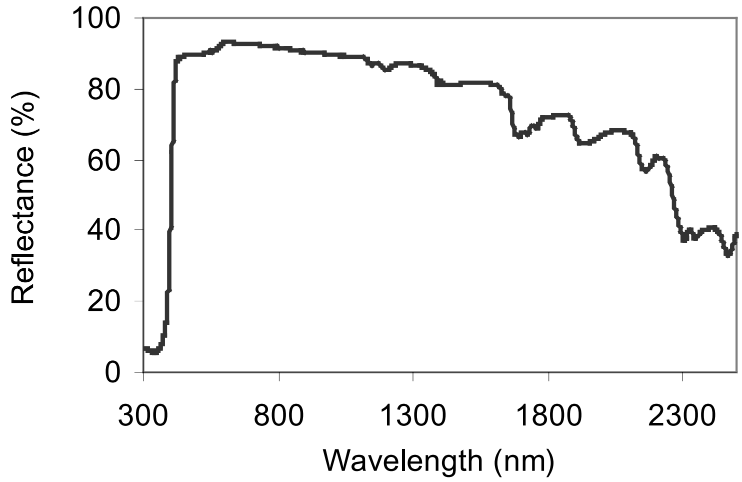



*Figure 5: The spectral reflectance of perform white*

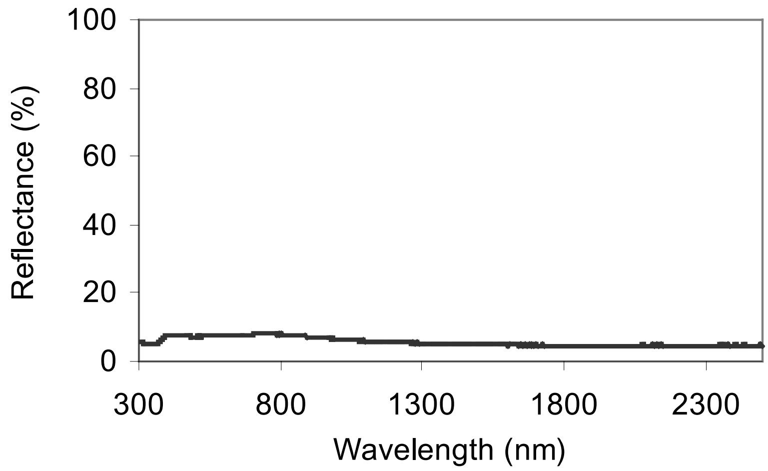



*Figure 6: The spectral reflectance of bioni roof 104*

All the tested coatings exhibit strong absorption in the UV range (300-400nm). The coatings “perform white”, “bioni perform sol 02”, “perform terra 20” and” perform flora 22” that are light colored, present very high reflectance values in the visible range (400-700nm) and quite high near infrared (700-2500nm) reflectance values. On the contrary, bioni roof 104 exhibits strong absorption over the entire range of the solar spectrum and bioni roof 102presents strong absorption in part of the visible range and very low reflectance in the near infrared part of the spectrum.

## 2.2 Calculation of the solar reflectance

The spectral reflectance data were used in order to calculate the solar reflectance of each sample The term solar reflectance (SR) designates the total reflectance of a surface, considering the hemispherical reflectance of radiation, integrated over the solar spectrum, including specular and diffuse reflection. The calculation was done by the weighted averaging method, using a standard solar spectrum as the weighting function. The spectrum employed is that suggested by ASTM (see standards ASTM E903-96 and ASTM G159-98). The values of solar reflectance are shown in Table 2.

| i | Coating code | Solar Reflectance |
|---|---|---|
| 1 | bioni roof 102 | 0.16 |
| 2 | perform flora 22 | 0.81 |
| 3 | perform terra 20 | 0.68 |
| 4 | bioni perform sol 02 | 0.79 |
| 5 | perform white | 0.84 |
| 6 | bioni roof 104 | 0.07 |

*Table 2. The calculated values of solar reflectance for the six coating samples*

All the coatings tested present quite high values of solar reflectance except from the brown “bioni roof 102” and the black one “bioni roof 104”. Among the six coatings tested the “perform white” and the “perform flora” had the highest values of solar reflectance (over 80%).

## 2.3 Measurement of the infrared emittance

The infrared emittance of the samples was also measured according to the ASTM E408-71 (2002): Standard Test Methods for Total Normal Emittance of Surfaces Using Inspection-Meter Techniques. The infrared emittance (e) specifies how well a surface radiates energy away from itself as compared with a black body operating at the same temperature. The instrument used for the measurements is the Devices & Services emissometer model AE. This emittance device determines the total thermal emittance, in comparison with standard high and low emittance materials. The results of the infrared emittance measurements are presented in table 3.

| i | Coating code | Infrared emittance (error ±0.02) |
|---|---|---|
| 1 | bioni roof 102 | 0.88 |
| 2 | perform flora 22 | 0.88 |
| 3 | perform terra 20 | 0.88 |
| 4 | bioni perform sol 02 | 0.87 |
| 5 | perform white | 0.87 |
| 6 | bioni roof 104 | 0.88 |

*Table 3. The measured values of infrared emittance for the six coating samples*

All the samples are characterized by quite high values of infrared emittance.

## 3. SIMULATION METHODOLOGY AND RESULTS

The scope of this study is to estimate the potential impact on cooling loads from the use of the six tested coatings on the building envelope. In order to perform the simulations TRNSYS thermal simulation software was used. The meteorological data are for the city of Athens, Greece and were taken from the METEONORM database. The calculations were performed with an hourly time step.

The base case building used in the simulation is a single story, flat roof house with a roof area of 50 $m^2$ and 2.6m height. It is oriented at the NE-SW axis, The U-value of the walls was considered to be 0.66 $W/m^2$ and the roof U-value is 0.47 $W/m^2$. On the NE and SW walls there are windows with double glazing (U-value 2.7 $W/m^2$) and total surface equal to 2.4 and 4.8 $m^2$ (20% and 17% of the corresponding wall area) respectively. The shading factor was set to 0.7.

Infiltration and ventilation rates were both set equal to 0.6 ACH and 1ACH respectively. The thermostat set point temperatures for cooling was set to26$^o$C and for heating to 20$^o$C. Regarding internal gains the following were assumed:

- the heat input per person was considered according to ISO7730,
- the artificial lighting was 8 $W/m^2$ (daily operational schedule between 19:00-24:00) and it was assumed that 30% of the input is contributed to the place as convective heat and the 70% as radiative.
- other gains from electrical equipment equal to 7 $W/m^2$ (daily operational schedule 12:00-14:00 and 17:00-19:00)

For the base case the solar reflectance of the building was considered to be 0.2, which is a typical value for concrete. Six different values of solar reflectance have been simulated each one corresponding to the experimental values measured for the six coatings (Table 2). The infrared emittance is set by the program to 0.9 by default.

The results of the simulations are presented in Figure 7.

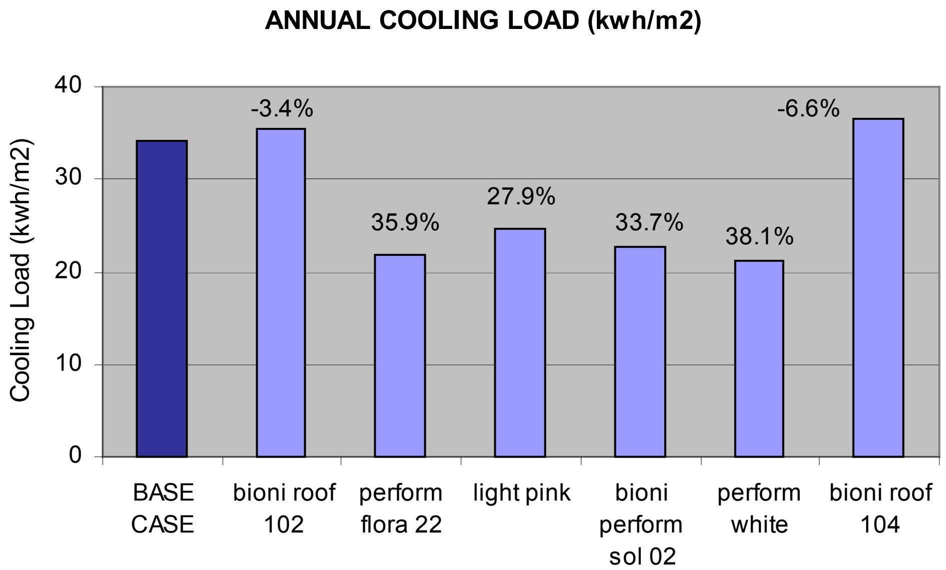



*Figure 7: The annual cooling loads and cooling load savings for the base case and each one of the six coatings*

The graph in figure 7 describes the cooling loads for the base case and the cooling loads for the six measured values of solar reflectance for each one of the tested coatings. The % cooling load change due to the different values of the envelope's solar reflectance was calculated and is also shown on the graph.

The results demonstrate that if the light colored coatings are applied on the building envelope, the energy demand for cooling is decreased. More specifically applying "perform white", "perform flora 22", "bioni perform sol 02" and "perform terra 20" on the building envelope would result in a decrease in cooling loads by 38.1%, 35.9%, 33.7% and 27.9% respectively.  A small increase in cooling loads was observed for the brown and black coatings.

Given that all the coatings are characterized by approximately the same value of infrared emittance and all other factors being equal, the main factor that affects the envelope's surface temperature and therefore the heat penetrating into the building is the solar reflectance of the coatings. The higher the value of solar reflectance the less heat penetrates into the building and less cooling energy is required to maintain a comfortable indoor thermal environment.

Additionally, in order to estimate also the heating penalty from increasing the solar reflectance, the heating load increase corresponding to “perform white”, the most reflective coating, was also calculated. It was found to be 12.3%, a lot less than the corresponding cooling saving of 38.1%. In general for cooling dominated climates the cooling savings far outweigh any heating penalty. This is mainly due to the fact that during winter, the solar angle is lower so the solar reflectance and absorption are not as important as during the summer when the sun is higher in the sky and solar radiation is hitting urban surfaces directly. Furthermore, the days during winter months are shorter and the ratio of cloudy to sunny days increases, so less total energy arrives on a surface to be absorbed or reflected over the same period of time as during the summer.

## 4. CONCLUSIONS

The following conclusions have been derived from the experimental assessment of the six coatings and the simulation study:

- All the coatings tested present quite high values of solar reflectance (except from the brown “bioni roof 102” and the black one “bioni roof 104”) ranging between 0.79-0.84
- Among the six coatings tested the “perform white” and the “perform flora” had the highest values of solar reflectance (over 80%).
- All the samples are characterized by quite high values of infrared emittance 0.87-0.88.
- Taking into account the high solar reflectance and infrared emittance values for the coatings “perform white”, “perform flora 22”, “bioni perform sol 02” and “perform terra 20”, they can be classified as cool coatings.
- Applying “perform white”, “perform flora 22”, “bioni perform sol 02” and “perform terra 20” on the building envelope would result in a decrease in cooling loads by 38.1%, 35.9%, 33.7% and 27.9% respectively.

The use of cool coatings is an inexpensive and passive solution that can contribute to the reduction of cooling loads in air-conditioned buildings and the improvement of indoor thermal comfort conditions by decreasing the hours of discomfort and the maximum temperatures in non air-conditioned residential buildings. The large-scale use of cool materials in an urban area leads also to indirect energy savings due to the increased solar reflectance that contributes to the reduction of the air temperature because of surface heat balance at the urban level.