Impact of using cool paints on energy demand and thermal comfort of a residential building

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Abstract

This work studies the role of using cool paints and/or thermal insulation on the thermal behaviour and energy demand of a residential building. Buildings with thermal characteristics representing both old and new constructions are considered; the results were obtained using the dynamic computer simulator ESP-r.

For a case-study building in Portugal, in the summer, it was found that an increase in roof and façade value of total solar reflectance from 50 % to 92 % reduces the maximum free-float indoor temperature between 2.0 ºC and 3.0 ºC in old construction (without thermal insulation), and between 1.2 ºC and 2.2 ºC in new construction (with thermal insulation). This has as a trade-off effect the decrease of the minimum indoor temperature of up to 1.5 ºC. The results of annual energy demand for heating show a maximum penalization of about 30 % when using cool paints. However, it was demonstrated that the cooling demand almost disappears, thus eliminating the need to install air-conditioning devices.

The analysis of two specific hot periods of real summer weather data shows that the sun's altitude is critical on which solution originates the highest temperature reduction.

1. Introduction

Since the 90s, the frequency and intensity of heat waves have increased (IM-I.P., 2012) and weather events like these are expected to be more severe in the future (Meehl et al., 2004). These phenomena have a negative impact on human health, decreasing indoor-thermal comfort in buildings and thus increasing energy consumption.

The worldwide energy consumption, particularly to obtain indoor thermal comfort in buildings, has had a constant growth. In Europe, between 1990 and 2005, the absolute level of final household energy consumption rose by an average of 1.0 % per year and, in 2005, the residential sector accounted for 26.6 % of the final energy consumption (EEA, 2008). In Portugal, the fraction of energy for indoor thermal comfort already has a significant impact in global energy demand, approximately 22 % of the energy used in residential buildings (INE et al., 2011).

Until 2020, the European Union (EU) is committed to reduce energy use by 20 %, referred to 1990 (EPC, 2010). To achieve this goal, the EU has imposed that all Member States must implement measures to apply minimum energy performance requirements for buildings and ensure the certification of building energy performance (EPC, 2002). According to these guidelines, the Portuguese government decided to classify buildings according to their thermal efficiency (MEI, 2006, MOPTC, 2006, MOPTC, 2006).

One of the strategies that can be used to decrease energy consumption is coating not only the façades, but also the roofs of buildings with special coatings called cool paints. There are two ways in which cool paints may contribute to control the heat load of a building: reflect the incident solar radiation and release heat by thermal emittance, where the heated surface dissipates the heat absorbed by emitting infrared (IR) radiation.

The reflectance is normally characterized by the so-called TSR index (total solar reflectance). The value of TSR is obtained by analyzing the reflectance over twenty specific wavelengths, which covers the solar spectrum (Lind et al., 1980).

The colour of a paint film depends on its visible reflectance spectrum. However, increasing the IR reflectance of coatings, which accounts for almost 52 % of the total solar radiation energy – see Figure 1, it is possible to make it to reflect more energy without interfering with the surface colour.

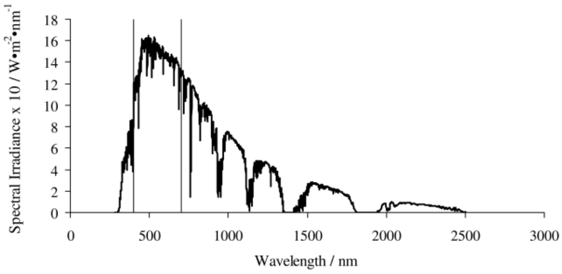

Fig. 1 – Terrestrial global spectrum, AM 1.5, 1000 W·m^{-2} – based on ASTM G173-03 (ASTM, 2008)

The so-called cool pigments can dramatically contribute to the TSR increase of paints, increasing the reflectance of the IR radiation. Another approach to make a paint film reflect solar radiation energy is to make the paint transparent to the IR radiation and use it over a high reflective primer.

Most of organic paints show a very high emittance. Usual exterior paints show normal emittance in the range of 90 %. It means that a paint film when heated radiates in the IR spectrum 90 % of the energy that a black body would do. The emittance is mostly not disturbed by the surface aging or cleanness.

A large number of studies were performed focusing on cool pigments, their incorporation in paints, the impact and the simulation of their use and their behaviour regarding aging. In 1931, Paul Kubelka and Franz Munk published an article of great relevance in this area, where they derived a mathematical equation for the reflectance of an achromatic paint as a function of the reflectance of the substrate and the coating thickness (Kubelka et al., 1931). Later, in 1947, Kubelka determined the validation range of the Kubelka-Munk theory and developed new formulas more adapted for practical use (Kubelka, 1947).

More recently, a great deal of research in this area has been conducted by Lawrence Berkeley National Laboratory (LBNL). For example, in 1998 and also in 2003, Akbari et al. studied the impact of a cool roof real application on the energy savings and comfort performance in buildings, at different locations in the United States (three commercial buildings in California and two small non-residential buildings in Nevada) (Akbari et al., 1998, Akbari, 2003). Both articles show cooling energy savings and drop of temperature in the summer. In 2004 and 2005, researchers from the same laboratory identified, characterized and studied the application of pigments to roof products in order to determine the effects of climate and solar exposure on the reflectance and the variability in colour over time (Miller et al., 2004, Levinson et al., 2005, Levinson et al., 2005). These studies have allowed LBNL to create a pigment database, which has free access (LBNL, 2012). In addition, the same workgroup, in 2005, assessed the effect of soiling and cleaning (wiping, rinsing, washing and bleaching) on the value of reflectance of roof coating samples (Levinson et al., 2005). They concluded that wiping restores some of the initial reflectance, but rinsing and/or washing are more effective and bleaching does not greatly increase the solar reflectance of a washed roof. Later, in 2010, the same authors presented the results of solar reflectance evaluation of three-year weathering tests on asphalt shingles, located in Berkeley, California, and in Houston, Texas (Berdahl et al., 2012) and they observed that, after six months, changes in solar reflectance are small and reduce by as much as 0.06 at three years. They also described methods for creating solar-reflective surfaces, first in 2007, presenting how to create non-white surfaces and their application to a wide variety of residential roofing materials, including metal, clay tile, concrete tile, wood and asphalt shingle (Levinson et al., 2007) and, in 2010, creating a prototype with the demonstration of a new process for coating concrete tile and asphalt shingle roofing products that uses a two-layer spray coating (Levinson et al., 2010).

Other authors made similar studies, for example, Ichinose et al., in 2009, performed an interesting study about the paint performance over time with respect to surface contamination and degradation of reflectivity through environmental exposure tests (Ichinose et al., 2009). This study demonstrates that panels coated with high-reflectivity paint can preserve thermal conditioning effects longer than the conventional coating panels. In 2011, Romeo and Zinzi also studied the impact of a cool roof application on the energy and comfort performance in an existing non-residential building located on the west coast of Sicily (Romeo et al., 2011). The effect of cool coatings in mitigating the thermal conditions was demonstrated and an average reduction of 2.3 ºC of the operative temperature, during the cooling season, was observed. This study also registered a 54 % reduction of the cooling energy demand.

Moreover, studies of cool roof performance have been carried out by computer simulation. Building simulation serves not only to predict indoor thermal behaviour of buildings and their energy consumption (annual cooling and heating load), but also to make environmentally-friendly design options possible. For example, in 2005, Luxmoore et al. used a dynamic and detailed energy simulation tool, DEROB-LTH, to create recommendation actions and strategies to mitigate temperature increase in residential buildings in Queensland, Australia (Luxmoore et al., 2005). Authors concluded that the heat island impacts can be mitigated through the use of light coloured or high albedo surfaces (roofs, walls, roads and other paved areas). Also Wang et al., in 2008, used dynamic thermal simulation software, EDSL Tas, to assess a retail shed, located in six different locations around the world, and with external surfaces painted with reflective coatings (Wang et al., 2008). The authors prove that the use of solar reflective coatings is effective in reducing cooling loads and overall electricity consumption, in particular in hot climates.

In this work, the application of cool coatings on a building was assessed using an open source simulator, ESP-r (ESRU, 2012). ESP-r is an integrated energy modelling tool for the simulation of the thermal, visual and acoustic performance of buildings and evaluation of their energy use associated with environmental control systems.

This paper focuses mainly on assessing the impact of cool coatings on the thermal behaviour and on the energy demand of a residential building. The study was conducted in buildings with different thermal comfort solutions and with cool coatings applied both on roof and façade surfaces. The results are especially relevant for addressing the thermal comfort during the renovation of old buildings since the introduction of insulation elements is normally significantly more expensive.

2. Simulation

In this work, a single villa was modelled on a yearly basis; it has two floors and a partially inhabited attic, as indicated in Figure 2. The ground floor has a living room (LR), a dining room (DR), a kitchen (KT), a toilet (TL), a hall (HL) and stairs (ST). The first floor consists of three bedrooms (BD), a suite (ST), a toilet, a bathroom (BR), a corridor (CR) and stairs. The attic has two parts that are inhabited, a playroom (PL) and stairs. Although all these zones were considered during the simulations, only some of them were used to obtain the average indoor temperature per floor. The zones considered are the living room, dining room and the kitchen on the ground floor, three bedrooms and the suite on the first floor and the playroom in the attic.

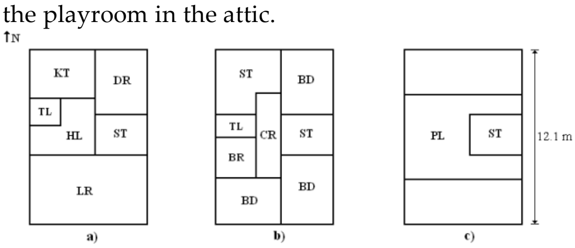

Figure 2 - Plant of the building: a) ground floor, b) first floor and c) attic

According to Portuguese law (MOPTC, 2006) a constant value of 0.6 air changes per hour was considered. The internal gains of the zones considered in the calculation of the indoor temperature were settled to 4 W·m^{-2}, following the recommendations of Portuguese law (MOPTC, 2006); for the remaining zones it was assumed to have 1 W·m^{-2} of internal gains (except for the two inhabited zones of the attic that were assumed to have no internal gains).

The building has a total area of 26.3 m^{2} of windows with clear glass. Taking into account the seasons, the existence of venetian blinds on windows was considered. These venetian blinds were considered as an additional layer over the windows, without any control system. Between June and September, exterior shading layers cover 75 % of each window, while during the rest of the year it was assumed 50 % of coverage.

3. Discussion and result analysis

The thermal behaviour and energy demand of a residential building were assessed using the dynamic computer simulator ESP-r (ESRU, 2012). The results were obtained in two steps: first a free float simulation was performed to evaluate the indoor temperature over the year and the second one with an HVAC system to assess the annual energy demand of the building. Two old constructions types, without thermal insulation, were assessed: single wall façade and double wall façade. A building with modern construction was also assessed: single wall façade with thermal insulation. The next sections detail the simulation results of a building located in Porto, Portugal (41°9'N 8°37'W). The weather data of Porto was obtained from the website of the Energy Efficiency and Renewable Energy (EERE).

3.1 Building 1 – single wall

Building 1 (BD1) is a single wall building (building whose exterior walls have masonry composed by single dense layer – the brick layer), with no thermal insulation, neither on the façades (external walls) nor on the roof (roof slab). The construction details are presented in Table 1, where all layers that compose the construction are described, from the exterior to the interior. This table also shows the thickness of each layer and the overall heat transfer coefficient – U. The specifications of each layer (e.g. conductivity, density, specific heat, emissivity and absorption) follows (Santos et al., 2006).

In the base case, the façades were assumed to have 50 % of TSR and 0.90 of emissivity; the roof was assumed to have 40 % of TSR and 0.90 of emissivity (clay tile). Simulations of a full year were performed, but for the thermal behaviour analysis only two specific periods were selected, one typical summer and winter week . According to the ESP-r Cookbook, typical weeks are determined taking into account, for each week of the year, the average and total heating and cooling degree days and solar radiation data. These values are compared with the seasonal values and the weeks with the least deviation (using user supplied weighting factors) are reported (ESRU, 2010). In Porto, the typical weeks considered were from June 26th to July 2nd and from January 22nd to 28th.

Const.	Layer	Thick. (MM)	U ($W{\cdot}M^{-2}{\cdot}K^{-1}$)
External wall	Coating Plaster Brick Plaster	0.2 30 190 10	1.3
Internal wall	Plaster Brick Plaster	10 110 10	2.1
Ground floor	Earth Gravel Concrete Asphalt Concrete Wood floor	300 300 300 10 20 20	0.7
Slab	Plaster Concrete Plaster	10 240 10	2.0
Window	Clear glass	8	5.6
Roof slab	Clay tile Air Plaster Brick Plaster	5 3 5 110 5	1.6

Table 1 – Construction details of the building with a single wall façade (BD1)

To analyze the energy demand, the annual cooling and heating needs to keep the temperature within the Portuguese reference values for residential buildings (MOPTC, 2006), between 20 °C and 25 °C, were taken into account. These values were obtained assuming an HVAC system working all over the year.

Two different studies were performed based on BD1: i) the impact of using cool paints, both on roof and façade surfaces, named BD1-CP, and ii) the impact of using thermal insulation, named BD1-TI.

3.1.1 Impact of using cool paints

The cool paint considered has 92 % of TSR and 0.90 of thermal emissivity; these correspond to experimental values obtained for a high quality white exterior paint. The thermal results of Porto location are presented in Table 6 and in Table 7 related to the typical summer week and the typical winter week, respectively. In these tables, T_{max} is the week average daily maximum temperature and T_{min} is the week average daily minimum temperature.

The indoor temperatures of the ground floor, first floor and second floor were separately determined as well as the exterior temperature of the building. According to the summer results, one can conclude that the thermal impact of cool paints is more significant on the second floor, followed by the first floor and finally the ground floor. Since the second floor has a larger exposed area to solar radiation, the cool paints can promote a higher cooling effect, 3.0 ºC on T_{max}. On the ground floor the cooling effect was smaller, 2.1 ºC.

In the typical winter week there is a non-desirable reduction of T_{min} between 0.8 ºC and 1.4 ºC due to the cool paint. Since cool paints are related to radiation control and the level of radiation in winter is expected to be low, these values show otherwise. Indeed, Figure 3 shows the daily direct solar radiation for both typical weeks; the winter irradiation is just 38 % smaller than the summer irradiation.

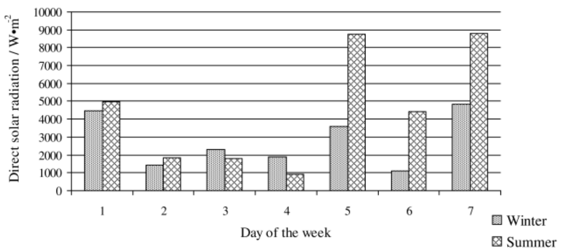

Figure 3 - Daily direct solar radiation over the typical weeks.

Table 8 shows annual cooling and heating demand of Porto and, although the annual energy demand has a heating load penalization of about 2.9 MWh per year, it was demonstrated that the cooling demand almost disappears, i.e. the building is comfortable even during the peak summer without mechanical cooling.

3.1.2 Impact of using thermal insulation

The impact of thermal insulation on the thermal comfort of BD1 was assessed assuming the use of 60 mm of expanded polystyrene (EPS) insulation, both on external walls and on the roof slab, as shown in Table 2. The conductivity value of this material was considered to be 0.042 $W \cdot m^{-1} \cdot K^{-1}$.

Const.	Layer	Thick. (MM)	U ($W \cdot M^{-2} \cdot K^{-1}$)
External wall	Coating	0.2	**0.5**
	Plaster	30	
	Insulation	**60**	
	Brick	190	
	Plaster	10	
Roof slab	Clay tile	5	**0.5**
	Air	3	
	Plaster	5	
	Insulation	**60**	
	Brick	110	
	Plaster	5	

Table 2 – Construction details of BD1-TI – in bold the differences from BD1

Table 7 shows the results of the typical winter week and it was found that the use of thermal insulation leads to an increase between 0.7 ºC and 2.1 ºC on T_{min}. On the other hand, Table 6 presents the values of T_{max}, in the typical summer week, where one can see that on the ground floor there was a reduction of 0.4 ºC, while on the first and second floors there was a temperature increase of 0.4 ºC. The temperature reduction on the ground floor is due to the thermal inertia of the ground, which leads to a lower ground temperature compared to the exterior air temperature. Therefore, the use of thermal insulation helps to keep or to reduce the indoor temperature of the ground floor. Table 8 shows that these temperature variations have an impact on the energy demand of the building; a not very significant reduction of the cooling demand was observed, while a drop in the heating demand of about 1.2 MWh per year was noted.

In order to perform a comparison of thermal insulation (BD1-TI) with the other two previous cases (base case – BD1 – and cool paints – BD1-CP), Figure 4 shows the hourly temperature history over the typical summer week. The exterior air temperature history is also presented.

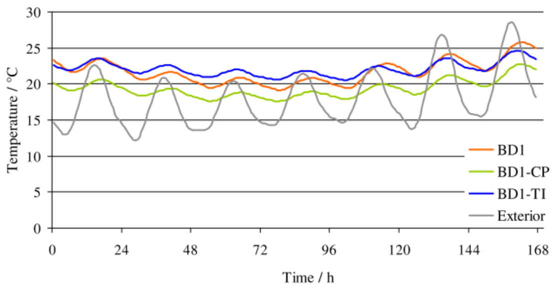

Fig. 4 – Hourly temperature history, over the typical summer week, for a single wall façade building.

Although the use of thermal insulation has the greatest reduction on the impact of exterior air temperature variations, decreasing the indoor temperature range, BD1-TI exhibits, most of the time, the highest indoor temperature. On the other hand, cool paints lead to a permanent and significant reduction in the indoor temperature.

3.2 Building 2 – double wall

BD2 has a double wall façade and no thermal insulation neither on the façades (external walls) nor on the roof (roof slab). Differences on construction details are indicated in bold in Table 3.

Const.	Layer	Thick. (MM)	*U* $(W \cdot M^{-2} \cdot K^{-1})$
External wall	Coating	0.2	**1.0**
	Plaster	30	
	Brick	**110**	
	Air	**60**	
	Brick	**110**	
	Plaster	10	
Window	Clear glass	8	**2.8**
	Air	**16**	
	Clear glass	**5**	

Table 3 – Construction details of the double wall façade building (BD2) – differences from BD1 highlighted in bold

Similarly to the previous case, two different studies were performed: i) the impact of using cool paints, both on roof and façade surfaces, named BD2-CP, and ii) the impact of using thermal insulation, named BD2-TI.

3.2.1 Impact of using cool paints

Results of BD2-CP are similar to those obtained for BD1-CP. The typical summer week shows a T_{max} reduction between 2.0 ºC and 3.0 ºC and between 0.8 ºC and 1.5 ºC on T_{min} in the typical winter week – see Tables 6 and 7. Table 8 shows that also in this case the cooling demand almost disappears and the annual heating demand has an increase of about 2.8 MWh per year.

3.2.2 Impact of using thermal insulation

The impact of thermal insulation on BD2 was assessed assuming again 60 mm of EPS insulation, both on external walls and on the roof slab, as shown in Table 4.

Table 7 shows that in the typical winter week T_{min} has an increase between 0.6 ºC and 2.7 ºC. In the typical summer week occurs a slight reduction of 0.2 ºC of T_{max} on the ground floor and an increase of 0.8 ºC on each of the other floors – see Table 6. In Table 8, one can see that these results lead to a decrease of about 4.1 MWh per year on heating demand and to a not significant variation of the annual cooling demand.

Const.	Layer	Thick. (MM)	*U* $(W \cdot M^{-2} \cdot K^{-1})$
External wall	Coating	0.2	**0.4**
	Plaster	30	
	Insulation	**60**	
	Brick	110	
	Air	60	
	Brick	110	
	Plaster	10	
Roof slab	Clay tile	5	**0.5**
	Air	3	
	Plaster	5	
	Insulation	**60**	
	Brick	110	
	Plaster	5	

Table 4 – Construction details of BD2-TI, where differences from BD2 are highlighted in bold

3.3 Building 3 – single wall with thermal insulation

BD3 follows the present Portuguese laws (MOPTC, 2006) concerning overall heat transfer coefficients. BD3 has a single wall façade with thermal insulation both on external walls and on the roof slab - construction details given in Table 5.
As BD3 already considers thermal insulation the impact of using cool paints, both on roof and façade surfaces, named BD3-CP was only assessed. Values of TSR and thermal emissivity of cool paints were 92 % and 0.90 respectively, as before.
Tables 6 and 7 show that in the typical summer week BD3-CP exhibits a T_{max} decreasing between 1.2 ºC and 2.2 ºC and, in the typical winter week, a maximum reduction in T_{min} of 1.1 ºC was observed. In Table 8, it was also observed that annual demand has a heating load penalization of about 1.2 MWh per year, although it was demonstrated that cooling demand almost vanishes.

3.4 Thermal comfort analysis in two specific real weather periods

Since ESP-r uses averaged weather data, hot or cool weeks especially do not happen, although in reality they occur. These outliers' conditions significantly influence the decision of houses-owners in terms of deciding for one or another architectural solution. In the following, two real and specific hot periods in Porto, from July 4th to 7th of 2010 and from September 2nd to 6th of 2012, are considered – Figure 5 and 6. Data shows daily maximum values of global solar radiation of about 1000 W·m^{-2} and maximum temperatures overpassing 30 °C.
Simulations considering the building with a single wall façade (BD1) were performed and the indoor temperature difference between the base case (BD1) and, the base case with thermal insulation (BD1-TI) and the base case coated with cool paints (BD1-CP) were calculated. The average of these temperature differences, $\Delta T_{average}$, for each period of time are shown in Tables 9 and 10.

Const.	Layer	Thick. (MM)	U (W·M^{-2}·K^{-1})
External wall	Coating Plaster Insulation Brick Plaster	0.2 30 60 190 10	0.5
Ground floor	Earth Gravel Concrete Asphalt Concrete Wood floor	300 300 300 200 200 20	0.5
Window	Clear glass Air Clear glass	8 16 5	2.8
Roof slab	Clay tile Plaster Insulation Brick Plaster	5 10 60 110 10	0.5

Table 5 – Construction details of BD3

Case	Temp. (ºC)	G. F.	1st F.	2nd F.
BD1	T_{max}	22.0	23.2	23.2
BD1-CP	T_{max}	19.9	20.7	20.2
	ΔT_{max}	**- 2.1**	**- 2.5**	**- 3.0**
BD1-TI	T_{max}	21.6	23.6	23.6
	ΔT_{max}	**- 0.4**	**+ 0.4**	**+ 0.4**
BD2	T_{max}	22.0	23.5	23.3
BD2-CP	T_{max}	20.0	21.0	20.3
	ΔT_{max}	**- 2.0**	**- 2.5**	**- 3.0**
BD2-TI	T_{max}	21.8	24.3	24.1
	ΔT_{max}	**- 0.2**	**+ 0.8**	**+ 0.8**
BD3	T_{max}	22.2	24.3	24.1
BD3-CP	T_{max}	21.0	22.5	21.9
	ΔT_{max}	**- 1.2**	**- 1.8**	**- 2.2**

Table 6 – T_{max} over the typical summer week of Porto

Case	Temp. (ºC)	G. F.	1st F.	2nd F.
BD1	T_{min}	9.5	10.6	9.1
BD1-CP	T_{min}	8.7	9.2	8.2
	ΔT_{min}	**- 0.8**	**- 1.4**	**- 0.9**
BD1-TI	T_{min}	10.2	11.8	11.2
	ΔT_{min}	**+ 0.7**	**+ 1.2**	**+ 2.1**
BD2	T_{min}	10.1	11.5	9.5
BD2-CP	T_{min}	9.3	10.0	8.5
	ΔT_{min}	**- 0.8**	**- 1.5**	**- 1.0**
BD2-TI	T_{min}	10.7	13.0	12.2
	ΔT_{min}	**+ 0.6**	**+ 1.5**	**+ 2.7**
BD3	T_{min}	10.8	12.6	11.9
BD3-CP	T_{min}	10.3	11.5	11.2
	ΔT_{min}	**- 0.5**	**- 1.1**	**- 0.7**

Table 7 – T_{min} over the typical winter week of Porto

Case	Energy demand (MWh/year)		
	cooling	heating	total
BD1	0.4	11.2	11.6
BD1-CP	≈ 0	14.1	14.1
BD1-TI	0.3	10.0	10.3
BD2	0.4	8.9	9.3
BD2-CP	≈ 0	11.7	11.7
BD2-TI	0.4	4.8	5.2
BD3	0.4	4.8	5.2
BD3-CP	≈ 0	6.0	6.0

Table 8 – Annual energy demand for studied cases

For the first period (July 4th to 7th), the building with thermal insulation (BD1-TI) shows the greatest indoor temperature reduction compared with the base case. However, it should be noted that on the second floor, the use of cool paints shows the highest temperature reduction, 4.2 ºC.

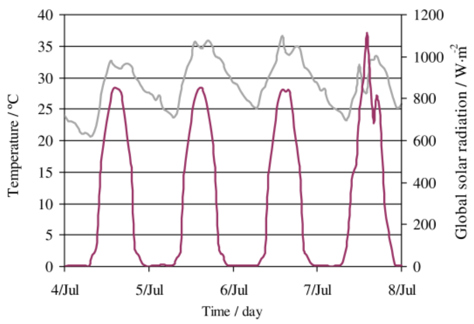

Fig. 5 – Exterior air temperature and global solar radiation histories from July 4th to 7th, 2010.

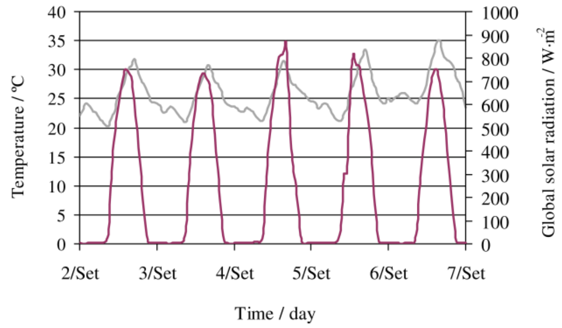

Fig. 6 – Exterior air temperature and global solar radiation histories from September 2nd to 6th, 2012.

Case	Temp. (ºC)	G. F.	1st F.	2nd F.	BD.
BD1	$T_{average}$	27.9	30.1	32.6	30.2
BD1-CP	$T_{average}$	26.1	27.9	28.4	27.5
	$\Delta T_{average}$	**- 1.8**	**- 2.2**	**- 4.2**	**- 2.7**
BD1-TI	$T_{average}$	24.9	26.6	29.0	26.8
	$\Delta T_{average}$	**- 3.0**	**- 3.5**	**- 3.6**	**- 3.4**

Table 9 – $\Delta T_{average}$ for the period of July 4th to 7th, 2010

Case	Temp. (ºC)	G. F.	1st F.	2nd F.	BD.
BD1	$T_{average}$	25.7	27.1	27.5	26.8
BD1-CP	$T_{average}$	24.1	25.0	24.5	24.6
	$\Delta T_{average}$	**- 1.6**	**- 2.1**	**- 3.0**	**- 2.2**
BD1-TI	$T_{average}$	24.6	26.3	27.5	26.1
	$\Delta T_{average}$	**- 1.1**	**- 0.8**	**≈ 0**	**- 0.7**

Table 10 – $\Delta T_{average}$ for the period of September 2nd to 6th, 2012

Interestingly, the opposite is observed in the second period (September 2nd to 6th): the greatest indoor temperature reductions are obtained always with cool paints. To understand these results it is necessary to note that the first period of time is close to the summer solstice, when the sun reaches 71º of altitude, and the second period happens when the sun reaches 55º of altitude. Since for the second period the sun strikes more strongly on the house's walls, the cool paint originates higher temperature reductions. The previous sections dealt with average results using an averaged weather database. However, real weather data originates a more complex reality where the effect of the proposed thermal comfort architectural solutions blurs.

4. Conclusion

The thermal performance of a residential building was simulated, assessing the impact of using cool paints and/or thermal insulation. In Porto – Portugal, although the use of cool paints shows that no annual cooling demand is required, the heating load penalization of about 30 % increases the total energy demand of the residential building.

The analysis of two specific hot periods of real summer weather data, not averaged, shows that the sun'S altitude is critical as to which cool paint or thermal insulation solution originates the highest temperature reduction; it was concluded that for lower sun altitudes the cool paints performed better.

5. Acknowledgement

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