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Research Article

Heat Radiation Control using Reflective Coating on Composite Slabs

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Abstract

Solar radiation is the main cause for high temperature of atmosphere. To protect from this radiation effect, human beings depend on air conditioners, air coolers, which causes more consumption of electrical power especially in summer. One of the most important envelop of any building is roof, because it protect the interior of building against extreme hot and cool conditions. By using reflective coating which has high thermal emission and low solar absorption on roof, we can reduce summer cooling loads of air conditioned buildings and can improve comfort levels for non-air conditioned buildings. In this study, we introduce high reflective materials like Bi_2O_3, TiO_2 to the normal cool cement and did a comparative analysis among them. By adding high reflective materials like BiO_2 and TiO_2 which are easily available at lower costs to cool cements, we can gain the temperature drop of 5.7°C below the roof, 2.7°C in room ambient temperature. By using this type of heat reflective coatings, we can reduce cooling loads in air conditioned rooms and can increase comfort levels in non-air conditioning rooms which reduces power consumption in summer seasons.

Keywords: Solar radiation, temperature, radiation effect, building roof, reflective coating.

Introduction

We know light energy from the sun reaches the earth in the form of electromagnetic radiation. In this the wave length region from 295-400 nm is Ultraviolet (UV) region in the electromagnetic spectrum. It generates vitamin D, which is little bit useful region for human beings. The wavelength region which is from 400-700 nm comes under visible region. The wavelength region which is from 700-2400 nm is Infrared region (IR) which is the heat producing region. Roofs which keep the interior of buildings cool by reflecting the IR rays coming from the sun is known as cool roofs. By adapting cool roof technology we can gradually reduce electrical power consumption in summer days. For non-air conditioned buildings, we can enhance thermal comfort for human beings in non-air conditioned cases. For this we have two methods. Those are thin film coatings and cool paint coatings. Thin film coatings have more disabilities while compared with the cool paint coatings. Production rate of thin film coatings are low, cost of manufacturing is high, difficult to apply on roofs. By adapting cool paint coatings we can overcame all the disadvantages of thin film coatings. When a light ray incident on the slab, absorption, reflection, transmission will be happen. Absorption will happen within the wavelength region 400-700 nm. After that region absorption will get minimizes. There are two types of reflection: Diffuse reflection and specular reflection. Transmission means passage of light ray through the object.

Infrared reflective pigments are classified into organic and inorganic pigments. The reflectivity and absorptivity of a pigment will depend upon its color. Generally white surface has high reflectivity compared to that of black surface. The inorganic reflective pigments are used in cool paints. These pigments have high reflectivity, low toxicity, high stability and they are chemically inert. We have numerous pigments available in market. Among those pigments, TiO_2 and Bi_2O_3 are most reliable and easily available. For this study we choose these two IR reflective pigments to attain high cooling effect.

Zhang *et al.* (2017) in their study made a building and they applied a retro reflective coating on all the building envelopes and did the heat transfer analysis through the building envelopes and attained a temperature drop of 2.4°C in the coated room ambient temperature. They used a retro reflective material which had reflectivity r=0.59 measured with the help of Spectrophotometer. An alternative X-ray shielding material based on coated textiles was used by Aral *et al.* (2017) who used Bi_2O_3 as an alternative X-ray shielding material coated on textiles due to its capability of high IR reflectivity. Due to its high reflectance, it can use as a shielding material for the workers who are working in X-ray laboratories. When it was compared with tungsten and barium sulphate powders, Bi_2O_3 attained high reflectivity.

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Near infrared reflectance properties of metal oxide nanoparticles were used by Jeevanandam *et al.* (2007) who used TiO_2 which had high reflectance and low absorptivity compared with other metal oxides like Cadmium stannate Fe_2O_3, Cr_2O_3, ZnS, Sb_2O_3, ZrO_2 and Zinc oxide.

Materials and methods

Cool paints: Cool paints are most used application to reflect the solar UV radiation on building envelopes. Roof is the most heat absorbing part compared to other all envelopes of building. Number of cool paints was available in the market, but all those are limited to temperature drop of maximum 1.5 to 2.5°C below the roof. The pigments used in the cool coatings have high reflectivity and solar emissivity. These cool paints mostly consist of $CaCo_3$, minerals, epoxy resin and metal oxides. By adding the metals or metal oxides which has high solar reflectivity and emissivity, we can improve the temperature drop below the roof up to 5 to 7°C.

Bismuth oxide: Bismuth oxide is the material that has high UV and X-ray reflecting properties. Compared to ZnO, BiO_2 has high solar reflectivity. Bismuth oxide due to its micro structure emits high solar reflectivity, high thermal emissivity and low absorptivity.

Titanium dioxide: Titanium dioxide (TiO_2) is the most widely used white pigment in paints. It has high brightness and a very high refractive index. The light passes through the crystal slowly and its path is substantially altered compared to air. If you have many small particles orientated in different directions, a high refractive index will lead to the scattering of light as not much light passes through. In lenses, high refractive index means high clarity and high polarizing power.

Considering the attributes of the above materials, we know that both BiO_2 and TiO_2 have high IR reflectivity and solar emissivity. By combining both metal oxides with cool cement, we can obtain a temperature drop below the roof of building and higher cooling effect can be produced. Compared to cool paint formed by mixing individual metal oxide, cooling cement formed by mixing both metal oxides may enhance the cooling rate produced.

Experimental design: Before a coating is applied, the roof is examined carefully for any signs of wear, cracks, tears, debris, or evidence of pounded water. Serious roofing problems were addressed. The next step is to thoroughly clean the roof surface in preparation of coating. Typically a pressure washer is used to remove all dirt and debris. The roof is allowed to dry for an appropriate amount of time. Once the roof is dry, it is inspected for a second time for any visible damages.

Fig. 1. Coated roof portion.

The coating can be applied with a roller or an airless paint sprayer. A paint sprayer is recommended for coating single roof systems. Each coat should be allowed to dry for four to six hours before applying a second coat. Generally, two to three coats are considered sufficient to effectively cover the roof (Fig. 1).

Procedure: Firstly we apply the normal cool cement which is dissolved in water on the cleaned surface. After that we mixed the cool cement and Bi2O3 in water in equal proportions and applied the mixture on another roof. We did the same for cool cement with TiO_2. Finally we made paint with the cooling cement, Bi_2O_3, TiO_2 in the ratios of 4: 2.5:3.5 in the water and applied it on another roof. Temperature readings on the coated roof, below the roof, inside room ambient temperature for coated rooms, and for non-coated room were tabulated for the 4 d period on 1 h time interval basis.

Results and discussion

Results of cool cement: The temperature readings obtained while application of cool cement on slab are shown in Table 1. From Table 1 we can observe that the maximum temperature drop obtained between the coatings is 2.5°C and room temperature difference between coated and un-coated room is 1.4°C.

Results for cool cement + Bi_2O_3: The temperature readings obtained while application of cool cement + Bi_2O_3 on slab are shown in Table 2. From the Table 2 we can observe that the maximum temperature drop obtained between the coatings is 3.0°C and room temperature difference between coated and un-coated room is 1.8°C.

For cool cement + TiO_2: From the Table 3 we can observe that the maximum temperature drop obtained between the coating is 3.6°C and room temperature difference between coated and un-coated room is 2.2°C.

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Table 1. Heat radiation effect controlled by reflective materials by using composite slab.									
Cool cement									
Day and time	without coating				with coating				
	Temp. on slab °C	Temp. below the slab °C	Temp. drop °C	Room temp. in the room °C	Temp. on coating °C	Temp. below the coating °C	Temp drop °C	Room temp. in the room °C	Cool effect °C
Day 1									
11:00 AM	46.2	44.1	2.1	28.3	44.1	41.6	2.5	26.8	1.5
12:00 PM	51.9	49.9	2	28.5	48.9	45.9	3	27.1	1.4
1:00 PM	53.1	50.9	2.2	29.1	51	49	2	28.2	0.9
2:00 PM	53.9	51.2	1.8	30.6	51.5	49.5	1.9	28.9	1.7
3:00 PM	49.2	47.5	1.7	30.2	47.6	45.1	2.5	28.8	1.4
4:00 PM	42.6	39.9	2.7	28.1	42.5	39.9	2.6	27	1.1
Day 2									
11:00 AM	46.3	46.3	2.2	28.4	44.2	41.6	2.6	26.8	1.6
12:00 PM	51.8	51.8	1.9	28.6	48.8	45.9	2.9	26.9	1.7
1:00 PM	53.2	53.2	2.3	29.2	51.1	49	2.1	28.3	0.9
2:00 PM	53.8	53.8	1.8	30.7	51.6	49.6	2	28.8	1.9
3:00 PM	49.1	49.1	1.6	30.3	47.7	45.1	2.6	28.4	1.9
4:00 PM	42.5	42.5	2.4	28.2	42.6	39.9	2.7	27.1	1.1
Day 3									
11:00 AM	46.2	44.1	2.1	28.3	44.4	41.9	2.5	26.9	1.4
12:00 PM	51.5	49.2	2.3	28.4	48.5	45.7	2.8	26.8	1.6
1:00 PM	52.8	50.3	2.5	29.1	51.3	49.1	2.2	28.2	0.9
2:00 PM	53.5	51.8	1.7	30.6	51.5	49.4	2.1	28.6	2
3:00 PM	49.2	47.7	1.5	30.4	47.8	45.3	2.5	28.1	2.3
4:00 PM	42.4	39.8	2.6	28.1	42.6	39.7	2.9	26.4	1.7
Day 4									
11:00 AM	46.6	44.3	2.3	28.1	44.3	41.9	2.4	26.8	1.3
12:00 PM	51.8	49.2	2.6	28.3	48.2	45.5	2.7	26.4	1.9
1:00 PM	52.4	49.7	2.7	29.4	51.4	49.3	2.1	28.1	1.3
2:00 PM	53.6	51.8	1.8	30.1	51.3	49.1	2.2	28.5	1.6
3:00 PM	49.5	47.9	1.6	30.3	47.2	44.7	2.5	28.2	2.1
4:00 PM	42.6	39.8	2.8	28.2	42.5	39.7	2.8	27.3	0.9
Day 5									
11:00 AM	46.7	44.5	2.2	28.2	44.2	41.9	2.3	27.1	1.1
12:00 PM	51.5	49.1	2.4	28.4	48.1	45.5	2.6	27.3	1.1
1:00 PM	52.3	49.7	2.6	29.4	51.3	48.4	2.9	28.1	1.3
2:00 PM	53.4	51.6	1.8	30.2	51.5	49.1	2.4	28.4	1.8
3:00 PM	49.4	47.9	1.5	30.4	47.3	44.8	2.5	28.1	2.3
4:00 PM	42.5	39.6	2.9	28.4	42.4	39.7	2.7	26.9	1.5

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Table 2. Heat radiation effect controlled by reflective materials by using composite slab.									
Cool cement + Bi_2O_3									
	without coating				with coating				
Day and time	Temp. on slab °C	Temp. below the slab °C	Temp. drop °C	Room temp. in the room °C	Temp. on coating °C	Temp. below the coating °C	Temp drop °C	Room temp. in the room °C	Cool effect °C
Day 1									
11:00 AM	46.2	44.1	2.1	28.3	44	40.6	3.4	26.5	1.8
12:00 PM	51.9	50	1.9	28.5	48.8	45	3.8	26.6	1.9
1:00 PM	53.2	51.1	2.1	29.2	51.1	48.1	3	27.6	1.6
2:00 PM	53.9	51.3	2.6	30.8	51.5	48.7	2.8	28.7	2.1
3:00 PM	49.5	47.8	1.7	30.2	47.8	44.9	2.9	28	2.2
4:00 PM	42.8	40	2.8	28.1	42.6	39.7	2.9	27	1.7
Day 2									
11:00 AM	46.5	44.2	2.3	28.1	44.1	40.8	3.3	26.4	1.7
12:00 PM	52.2	50.5	1.7	28.4	48.8	45.2	3.6	26.5	1.9
1:00 PM	53.5	51.3	2.2	29.3	51.3	48.4	2.9	27.4	1.9
2:00 PM	54.2	51.7	2.5	30.5	51.5	48.4	3.1	28.5	2
3:00 PM	49.8	48.2	1.6	30.2	47.6	44.4	3.2	28	2.2
4:00 PM	43.1	40.5	2.6	28.3	42.4	39.2	3.2	27.1	1.2
Day 3									
11:00 AM	46.3	44.1	2.2	28.4	44.3	41.2	3.1	26.5	1.9
12:00 PM	52.1	50.5	1.6	28.1	49.1	45.7	3.4	26.6	1.5
1:00 PM	53.2	50.9	2.3	29.2	51.4	48.7	2.7	27.8	1.4
2:00 PM	54.1	51.7	2.4	30.4	51.6	48.7	2.9	28.3	2.1
3:00 PM	49.6	47.9	1.7	30.1	47.8	44.6	3.2	28.1	2
4:00 PM	43.2	40.5	2.7	28.2	42.8	39.5	3.3	26.5	1.7
Day 4									
11:00 AM	46.4	44.3	2.1	28.3	44.1	41.7	2.4	26.6	1.7
12:00 PM	52.2	50.2	2	28.5	49.3	45.9	3.4	26.8	1.7
1:00 PM	53.3	50.7	2.6	29.2	51.5	48.9	2.2	27.7	1.5
2:00 PM	54.2	51.4	2.8	30.8	51.2	48.5	2.7	28.2	2.6
3:00 PM	49.7	47.5	2.2	30.2	47.5	44.9	2.6	28.3	1.9
4:00 PM	43.3	41.5	1.8	28.1	42.6	39.6	3	26.5	1.6
Day 5									
11:00 AM	46.1	44.2	1.9	28.2	44.1	40.5	3.6	26.4	1.8
12:00 PM	51.8	50.1	1.7	28.4	48.9	44.9	4	26.6	1.8
1:00 PM	53.1	51.2	1.9	29.1	51.2	48.1	3.1	27.6	1.5
2:00 PM	53.8	51.4	2.4	30.7	51.6	48.6	3	28.4	2.3
3:00 PM	49.4	47.9	1.5	30.1	47.9	44.8	3.1	28.1	2
4:00 PM	42.7	40.1	2.6	28.1	42.7	39.6	3.1	26.9	1.2

*Corresponding author

Table 3. Heat radiation effect controlled by reflective materials by using composite slab.

Cool cement + TiO_2

Day and time	without coating				with coating				
	Temp. on slab °C	Temp. below the slab °C	Temp. drop °C	Room temp. in the room °C	Temp. on coating °C	Temp. below the coating °C	Temp drop °C	Room temp. in the room °C	Cool effect °C
Day 1									
11:00 AM	46.2	44.1	2.1	28.3	44.3	40.8	3.5	26.4	1.9
12:00 PM	51.9	49.9	2	28.5	49	45.1	3.9	26.8	1.7
1:00 PM	53.2	51	2.2	29.1	51.3	48.2	3.1	27.8	1.3
2:00 PM	53.9	51.2	2.7	30.6	51.8	48.9	2.9	28.3	2.3
3:00 PM	49.5	47.6	1.9	30.2	48	44.8	3.2	28.1	2.1
4:00 PM	42.8	39.9	2.9	28.1	42.8	39.5	2.3	27	1.1
Day 2									
11:00 AM	46.3	44.1	2.2	28.4	44.5	40.7	3.8	26.6	1.8
12:00 PM	51.5	49.2	2.3	28.6	48.9	45.2	3.7	26.8	1.8
1:00 PM	53.4	51.1	2.3	29	51.2	48.1	3.1	28	3
2:00 PM	53.8	51.3	2.5	30.4	51.8	49	2.8	28.3	2.1
3:00 PM	50.1	48	2.1	30.2	48.1	44.9	3.2	28.1	2.1
4:00 PM	43.1	39.9	3.2	28.2	42.9	39.7	3.2	27.2	3
Day 3									
11:00 AM	46.2	44.1	3	28.4	44.3	40.5	3.8	26.5	1.9
12:00 PM	51.5	49.2	2.4	28.4	48.8	45.6	3.2	26.6	1.8
1:00 PM	53.2	51	2	29	51.5	48.3	3.2	27.8	1.2
2:00 PM	53.8	51.3	2.3	30.3	51.8	48.9	2.9	28.4	1.9
3:00 PM	49.5	57.6	1.6	30.1	48.1	45.2	2.9	28.2	1.9
4:00 PM	43.1	39.9	3.1	28.4	43.2	40.1	3.1	27.5	0.9
Day 4									
11:00 AM	47	44	3	28.4	44.3	40.5	3.8	26.5	1.9
12:00 PM	51.5	49.1	2.4	28.4	48.8	45.6	3.2	26.6	1.8
1:00 PM	53.2	51.2	2	29	51.5	48.3	3.2	27.8	1.2
2:00 PM	53.8	51.5	2.3	30.3	51.8	48.9	2.9	28.4	1.9
3:00 PM	49.8	48.2	1.6	30.1	48.1	45.2	2.9	28.2	1.9
4:00 PM	43.2	40.1	3.1	28.4	43.2	40.1	3.1	27.5	0.9
Day 5									
11:00 AM	46.4	44.2	2.2	28.5	44.4	40.9	3.5	26.5	2
12:00 PM	52	50	2	28.6	49.1	45.2	3.9	26.8	1.8
1:00 PM	53.1	50.8	2.3	29.1	51.2	48.3	2.9	27.9	1.2
2:00 PM	54	51.2	2.8	30.5	52	49	3	28.4	2.1
3:00 PM	59.7	47.8	1.9	30.2	48.2	45.1	3.1	28.2	2
4:00 PM	43	40	3	28.3	42.9	39.7	3.2	27.2	1.1

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Cool cement + *Bi_2O_3+ TiO_2*: From the Table 4 and Fig. 7, we can observe that the maximum temperature drop obtained between the coating is 5.7°C and room temperature difference between coated and un-coated room is 2.8°C, which is efficient composition among all.

From the present study, by comparing the room temperature of un-coated room with all the types of coated room temperature, it was noted that the coating which is made by combination of cool cement, Bi_2O_3 and TiO_2 gave higher cooling effect and we can mention it as an efficient coating.

Conclusion

By using cool cements which are available in markets we can control the heat radiation effect but not effectively. By adding high reflective materials like BiO_2 and TiO_2 which are easily available at lower costs to those cool cements, we can gain the temperature drop of 5.7°C below the roof, 2.7°C in room ambient temperature. By using this type of heat reflective coatings, we can reduce cooling loads in air conditioned rooms and can increase comfort levels in non-air conditioning rooms which reduces power consumption in summer seasons.

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