ISSN 2320-9984

Volume 7 Issue 3 | September 2019 ISSN: 2320-9984 (Online)

International Journal of Modern Engineering & Management Research

Website: www.ijmemr.org

# Analysis of Cool Roof Techniques for Energy Saving in Buildings

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***Abstract*—*Cool roof technology is used to minimize the volume of heat or energy absorbed by a roof surface and maintaining the temperature in buildings in summer season. Aim of this thesis is to provide the comfort in summer by using cool solar reflective materials. Solar reflective materials have two properties; one is high thermal emittance and second is high solar reflectance, so that reducing the utilization of electrical energy. For roof insulation, we used solar reflective materials in our experiments. The thermal performance of asbestos sheet roof and concrete roof without insulation and with insulation has been analyzed by performing experiments to building. By applying solar reflective paint (with high reflective coating), a drop of about 4.9°C in peak hours occurs and save about 300 kWh in the summer season, in corresponding to non-insulated roof and flat roof energy loads of residential buildings. The results are calculated for residential buildings in a claggy climate like Jabalpur. The advantages of cool roofs techniques are to reduce the global warming, urban heat island, air temperature and it makes a more comfortable and healthier environment.*

***Keywords:*— *high thermal emittance, high solar reflectance, claggy climate, solar reflective, sustainable earth,*

## 1. INTRODUCTION

### *History of cool roofs in India*

Energy and Environment are the two key words of today‘s Architecture. When buildings of today go in search of methods and means to decrease their impact on energy and environment, culturally rich countries like India, have a history of being energy efficient and environmentally friendly in their construction activities. Many vernacular technologies are energy efficient and sustainable, though some of them are no longer implementable because of the changed cultural, ecological, and economic situations of the country. In this regard, the key challenge is to understand the benefits of those techniques and find ways to integrate them to today‘s buildings. In hot climates, most of the buildings of this century tend to depend on air conditioning systems and electricity, and are unable to adapt to the present day climate. Most of these modern building are very poorly designed to withstand the prevailing climatic conditions [1]. This resulted on dependency of cooling system which in turn absorb maximum amount of electricity. Buildings of modern day tend to behave like boxes created out of glass and RCC. Lack of proper shading, over glazing, thin skin, inefficient air conditioning systems are some prominent features of the energy consuming ghost buildings. In contrast to the modern building the vernacular building are more versatile to the local climate and environment. Use of thick walls, wind catches, ponds, courtyards, is some design principle which comprises use of low-energy, comfort, durability and affordability. Many of these vernacular buildings tend to use local material, passive heating and cooling, and renewable energy systems. Hence, taking a step back into the future will be the need for a sustainable earth [2].

Building roofs have a major share in adding to the head load in the buildings. Being exposed to direct solar radiation all through the day, with maximum surface area exposure, roofs act as paths of heat gain into the interior spaces. Traditionally, in India, building roofs which are flat act as multipurpose spaces. Flat roofs of house in India are gathering grounds for many activities. During the day, they act as drying yards, and during the night they turn to sleeping platforms. Especially in a multi family culture that was once very much prevalent in India, terraces are the spaces for kids to play, and families to gather. In North Western India, in states such as Gujarat and Rajasthan, it‘s a common practice to coat the roofs white, using lime and chalk. China mosaic also is another popular practice in which women arrange the broken tiles (mostly white) in a spider web pattern. Based on the local climate of the place, and availability of the material, the roof finishes use to vary. The white coating always helped to keep the terrace surface cool, and emit less radiation during the cooler parts of the day, when the roofs are occupied for other activities. This in turn restricted the heat flow into the building all through the day [1].

## 2. A COOL ROOF

A cool roof technology is used to maintain temperature of our environment in indoor and outdoor also, by using white painting of top portion of roof. During construction, architects can either use material for cool roofing or modify the actual roofs with some cool roof technologies. It can consist of paint (reflective type), reflective tiles or a covering sheet. We can use cool roof technologies in any type of building, but we should consider the all factors and climate change before installation process. Temperatures of about 60ºC or above in the summer season can reach in standard or dark roofs. In these same conditions, a cool roof can work better and save energy.

### *Working of Cool Roof*

As we know solar energy has two properties one is solar reflectance and second is thermal emittance and the combined temperature effect of these two properties working together. Cool roofs are constructing with those materials which have both properties. Cool Roof Rating Council (CRRC) has defined, a cool roof reverse and release the heat of sun back to the sky rather than transferring it to the building. Both the properties of cool roof are measured from 0 to 1 and the higher the value. Figure 1 shows the working of cool roof as explain by CRRC.

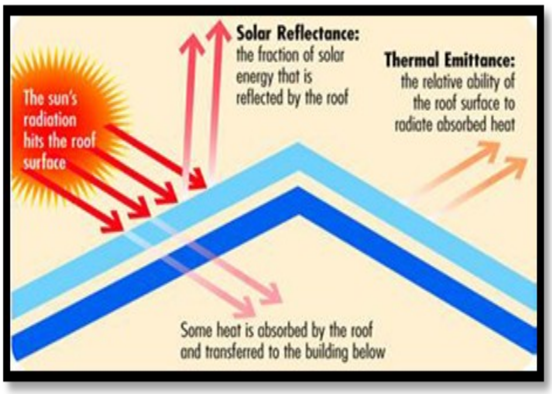


*Figure 1: Working of a Cool Roof*

Basically Cool roofs are made with materials with the both desired properties.

- High solar reflectance
- Emittance

## 3. SOLAR REFLECTANCE

The total amount of (in percentage) reflectance of solar energy from surface is called Solar Reflectance. It is the part of the incident solar energy (reflected by the surface). It consists of a wavelengths spectrum, containing ultraviolet, infrared and visible. The solar energy distribution as a function of wavelength is shown in Figure 2. Surface materials which have higher solar reflectance can reflect solar energy and also it will have best performance in decreasing roof heat gain. In the visible light range, color is a best sign to show solar reflectance. It increases from a dark-color surface to a light-color surface with reflectance [2].

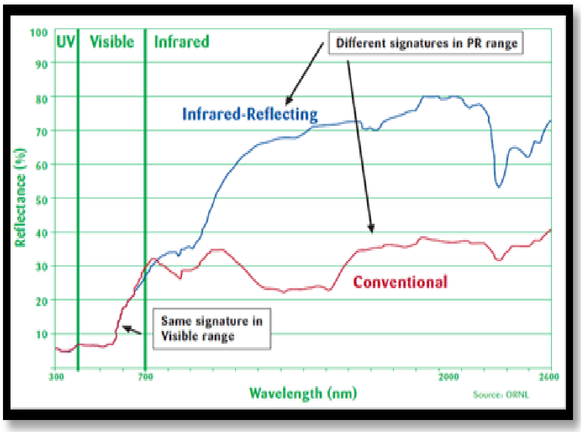


*Figure 2: Solar Reflectance effect of a Cool Colored Coating*

Solar reflectance of dark-color roofing materials is about 0.05 to 0.19, whereas light-color roof surfaces have about 0.75 or higher. With the application of special coating on the roofing materials (cool roof technology) we can increase the solar reflectance in the infrared range. With this technique, visual appearance of the roof is same, but is much cooler. By applying cool color technology on surface has higher reflectance in the infra-red range and remains cooler.

Researchers have developed methods to find out solar reflectance by determining how much a material reflects energy at each wavelength of solar energy, then calculating the average of all values. Conventional roofing materials have low solar reflectance of about 10 to 20 %, which means they absorb 80 to 90 % of the energy arrive them rather than reflecting the energy back to the atmosphere. Cool roof materials have a high solar reflectance of more than 68%, absorbing and transferring to the building 32% or less of the energy that reaches them.

## 4. THERMAL EMITTANCE

No roof is a perfect reflector, as all surfaces absorb some solar energy as heat. Part of the retained heat will be emitted back to the environment in the form of infrared radiation. Thermal emittance is a ratio between what a warm or hot surface emits and what a perfect blackbody emitter would emit at the same temperature. It has a value between 0 and 1, with a low emittance roof becoming relatively hotter than a high emittance roof since it is not as effective at getting rid of the retained heat.

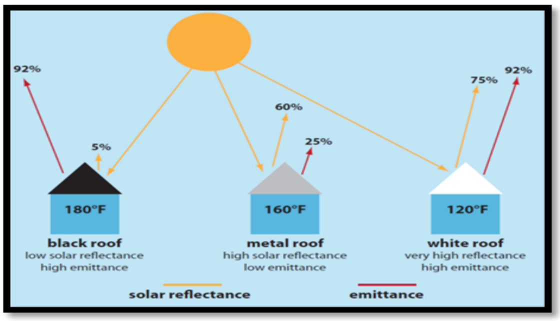


*Figure 3: Combined Effects of Solar Reflectance and Thermal emittance on Roof Surface Temperature*

The thermal emittance of most common roofing materials is approximately 0.80. Metallic surfaces are the exception, since bare metals become extremely hot in the sun. For example, in one outdoor experiment, a bare clean sheet of galvanized steel with a solar reflectance of about 0.38 reached temperatures nearly as high as a black surface. Thermal emittance of metallic surfaces varies widely between 0.20 and 0.60, depending on surface conditions.

The reflectance and emittance of bare metals are very sensitive to the smoothness of the surface and the presence of surface oxides, oil, film, etc. Metal roofing is available with pigmented polymeric coatings, similar to paint. These coatings are used to protect the metal panels, and sometimes also to provide a more appealing appearance; they can also keep the roof cooler. For example, metal roofing with cool white coatings (Siliconized Polyester White and Atlanta Metal Products Kynar Snow White) have emittances as high as 0.85.

## 5. ROOF REFLECTIVITY

A reflective roof is typically light in colour and absorbs less sunlight than a conventional dark colour roof. Less absorption of sunlight lowers the roof‛s surface temperature, reducing the heat transfer through the roof. This property of the roof makes it a Cool Roof.

When the roof surface is painted white or treated white, the surface temperature of the roof decreases. This further decreases the effective temperature difference between the outdoor and the indoor thereby reducing the heat gain into the rooms through the process of conduction which can be measured using the formula:

**Q= UA (delta t)**

Where, Q= heat transfer rate (W)

U= Coefficient of heat transfer/ Conductance of the roof ($W/m^2$ K)

A= Surface area ($m^2$)

delta t= temperature difference between the outdoor and indoor (K).

## 6. ROOF EMISSIVITY

Emissivity of the roof material defines the ability of the material to radiate out the absorbed heat. All the roof materials except metals generally are having an emissivity of 0.9. Emissivity of the metal roof is around 0.5 due to which the rooms with metal roof have less possibility to get cooled naturally. Roofing materials with less emissivity are appropriate in cold climates [7].

## 7. PERFORMANCE & DURABILITY OF COOL ROOF COATINGS

There are two main types of cool roof coatings: cementations and elastomeric. Cementations coatings contain cement particles. Elastomeric coatings include polymers to reduce brittleness and improve adhesion. Some coatings contain both cement particles and polymers. Both types have a solar reflectance of 65 percent or higher when new and have a thermal emittance of 80 to 90 percent or more. The important distinction is that elastomeric coatings provide a waterproofing membrane, while cementations coatings are pervious and rely on the underlying roofing material for waterproofing. In a present time many types cool (coating) materials and paint are available in the market [4].

### *Coating Adhesion*

- Surface preparation
- Primer selection
- Primer & top coat application
- Correct weather conditions during & immediately after application

### *Coating Durability*

- The durability of a roof coating is determined primarily by the type, quality and quantity of the binder and pigments in the coating.
- Durability is also determined by the application process, the weather conditions during and after application, the suitability and quality of the primer and the total applied coating thickness.
- Gloss coatings are more durable and have higher solar reflectance than semi-gloss, low sheen or flat coatings due to dirt moisture and surface light refraction.

It is concluded in many research papers that one of the ways of reducing energy generation is to reduce the demand for air conditioning. Engineers and architects should investigate more in researching different passive and active strategies to reach the best possible solution for thermal comfort. This can be done by using less energy and by natural climatic control for their buildings instead of relying on machines for cooling which are electricity dependent, and take part in ruining the environment.

Mainly in summer, thermal comfort is always the main concern in subtropical climate regions like Jabalpur. Using insulators with good thermal resistance for roofs, either during the designing and construction of the building, or during renovation, are usually more cost-effective and can reduce a considerable amount of the energy that is consumed in cooling. Cool roofs by applying insulators in the form of solar reflective materials are one of the cost-effective passive strategies that install easily, reduce heat gain, and improve thermal comfort in warm climates. From the above studies, it can be said that in building regulations, it should be mandatory in every country (having a hot climate) to install cool roofs, for this being the least expensive option to achieve the energy conservation and thermal comfort. From here, the objective of research comes out: to reduce the amount of energy used to reduce cooling energy demands during the summer by focusing on the cool roof as a solution.

The experimental study in this research covers solutions for reducing the inside temperature by applying the passive strategy in the form of insulators on the roof for low-rise and medium-rise residential buildings in Jabalpur, India. The research is divided into two parts; in the first part, experiments were performed with and without using insulators and observed data for ambient temperature and surface temperature. The results of this research on existing residential buildings show a significant reduction in thermal load and energy consumption. Parameters observed and equipment are hygrometer and infrared thermometer.

**Table 1: Building's Details**

| Room | Floor area | Roof Type | Roof finishing | Wall Type | Occupancy |
|---|---|---|---|---|---|
| 1 | 3.66m x 3.35m | Concrete | Cement | Brick Wall | 2 person |
| 2 | 3.05m x 3.35m | Concrete | Cement | Brick Wall | 2 person |

**Table 2 : Insulator's Details**

| Room Case number | Insulators | K - value | Reflective Index | Emissivity | Thickness | Cost/ $m^2$ (Rs.) | Durability |
|---|---|---|---|---|---|---|---|
| Case 1 | SRP | 0.09 | 0.88 | 0.913 | 2 coats | 100 | 5 years |
| Case 2 | Ceramic Tiles | 1.3 | 0.6 | 0.9 | 10 mm | 300 | 10 years |

## 8. METHODLOGY

### *Methodology Adopted for Observations*

The following procedure is adopted for taking observations:

- Continuously at least 3 days' readings of temperature and humidity in extreme summer in the month of May;
- Applying the scheduled insulator;
- Readings after applying insulators (observing in almost similar climatic conditions as at the time of no insulator).

### *Methodology Adopted for Analysis of Data*

Method is to determine the exact reduction in inside temperature. The readings were observed keeping similar temperatures as in no insulation. The roof is selected for the experiments are shown in Figure 4.

*Figure 4: Selected Roof for insulation*

The main two variables were selected for the roof: type of roof (concrete and asbestos sheet) and insulation material. These resulted in five different possibilities for roof insulation in two different types of roofs by consecutive alteration. The aim was to evaluate the best insulator with the optimum solution for each type of roof capable of taking out the most suitable and cost-effective energy efficient solutions in order to minimize heat transfer from the roof in the summer season. The experiments on the five proposed roofs were performed for the actual residential building chosen for the study.

## 9. RESULT AND DISCUSSION

Temperatures observed when outside conditions are similar in all the cases. Approximately similar weather data is observed in no insulator and with insulators. Ambient air temperature in all cases at different timings is shown is in tables. The temperature differences, decrease in temperature, and net percentage decrease in temperature are tabulated in Tables.

**Table 3: Decrease in Room Temperature after Applying Insulator of Room No. 2 (T) in °C & in Percentage**

| Time | Observed Temperatures | | Reduction in Temperatures | |
|---|---|---|---|---|
| | Without Insulator | With Insulator (SRP) | °C | % |
| 9:00 AM | 31.2 | 30.1 | 1.1 | 3.5% |
| 12:00 NOON | 37.9 | 33.2 | 4.7 | 12.41% |
| 3:00 PM | 38.5 | 34 | 4.5 | 11.72% |
| 6:00 PM | 38.2 | 33.2 | 5 | 12.6% |
| 9:00 PM | 35.4 | 33.6 | 1.8 | 5.2% |

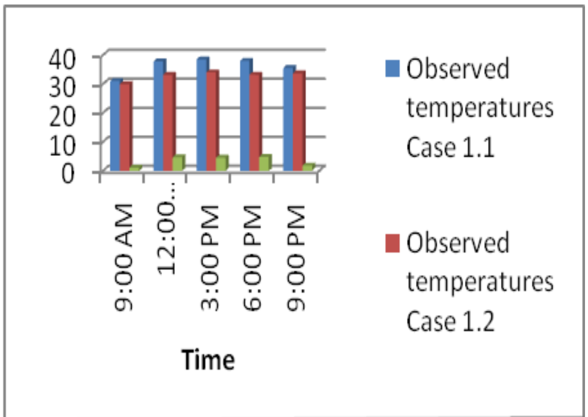


*Figure 5: Temperature difference inside room no 1*

**Table 4: Decrease in Room Temperature after Applying Insulator of Room no. 2 (T) in °C & in Percentage**

| Time | Observed temperatures | | Reduction in temperatures from | |
|---|---|---|---|---|
| | Without Insulator | With Insulator (Tiles) | °C | % |
| 9:00 AM | 32.1 | 29.5 | 1.4 | 4.4% |
| 12:00 NOON | 38.4 | 33.9 | 3.3 | 8.6% |
| 3:00 PM | 39.2 | 33.9 | 3.5 | 8.9% |
| 6:00 PM | 37.5 | 34.2 | 2.2 | 5.9% |
| 9:00 PM | 36.2 | 32.5 | 2.2 | 6.1% |

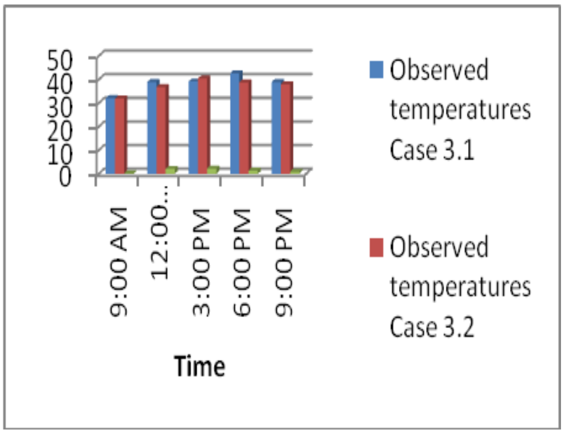


*Figure 6: Temperature difference inside room no 2*

In this paper, a method is proposed, and evaluated for the cool roof as a way to improve thermal conditions indoors. During the summer, in air-conditioned or nonair-conditioned buildings, insulation helps in lowering energy consumption and improves thermal comfort. Hence, the use of cool materials in an urban area at large scale leads to significant energy savings due to the high solar reflectivity of insulators used. This results in the reduction of the air temperature because of surface heat balance at the urban level. Insulation on roofs proves much more effective than wall insulation (inside temperature about 6°C–7°C reduces). For a climate like Jabalpur, the solar reflective material on roofs gives sufficient reduction in inside temperature. This research concludes that by applying solar reflective material, one can achieve the best result at very low rates.

From the results, it is clearly seen that the optimum solution through insulation used either on the roof or wall, is by applying Solar Reflective Paint, which is cost-effective and durable. Tiles are costly but give good results for a long time. SRP as an insulator on the roof is the most economical and effective solution in places of hot climatic conditions. Lime is the best solution, but its maintenance is required almost every year.

## 10. CONCLUSION

Cool insulators through roofs, which has been validated using simulation. Solar reflective paints can increase thermal comfort for the inhabitants with no energy burdens from HV/AC systems on existing roof and can be used in effective forms as passive cooling techniques. The maximum reduction in temperature is found by applying SRP on the roof (4.8°C). Also, it is the optimum solution for such types of roof.

This study is performed for achieving indoor thermal comfort as well as reducing energy consumption for low/medium-rise residential buildings in subtropical humid climates. The results obtained from this study can be applied in similar climates to Jabalpur's and the methodology applied can be applied to other climatic conditions. With this proposed cool roof, other passive strategies are recommended for use, such as wall insulation and solar shading for façades, together with double or triple glazing for windows with low U value. The proper window-to-wall ratio is also important for proper ventilation and lighting. The results of the simulations also provide an optimal solution of insulators for both types of roofs on central Indian weather conditions. The cost of insulators is affordable for middle-class people and is very low in comparison to other building cooling systems. Also, the installation of insulators in existing buildings does not disturb the occupants, as they are easy to install.

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