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# Roof Insulations for Public Buildings in Hot Climate

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**Abstract:** ***Due to higher solar radiation roofs are the most affected area in the envelope of the building, hence giving an utmost importance to thermal behavior as the main concern to compare any cool roof. Various calculations are taken to find the thermal performance and then comparison in thermal behavior is carried out. Limitation of any technique is critical importance along with its economic effect to select any type of cool roof. This research compares various cool roofs on basis of thermal behavior, economy and their limitations. This research will help the architects and designers to make wise choice regarding perfect selection of roofing material in case of thermal behavior, economy and limitation of any technique or material to make the roof cooler.***

**Keywords:** Thermal behavior, Cool Roof, Hot climate

## 1. Introduction

India having a very wide range of climatic condition depending upon its geography from north to south, also it has tropic of cancer passing through it, making it typically a tropical climatic region. Hot summers are the main problem faced in this region such as, Rajasthan, Gujarat, Maharashtra, Delhi and Madhya Pradesh. The maximum heat gain in the building is through envelope where roof is the major area of concern as horizontal radiation is the highest one.
Roofs can be broadly classified in the following two main types:

- Pitched or sloped roofs.
- Flat terraced roofs.

### 1.1 What are "Cool Roofs"?

The roof which reflects the incident sunlight and also which emits back to atmosphere some of the absorbed radiations, rather conducting it through roof inside the building. This helps in maintaining the temperature making the roof and building cooler with lower surface temperature. Cool Roof attributes to exterior surface which mainly act as reflective surface, having higher reflectance and low conductance than typical roof.

Solar reflectance and emission are the two main thermal property. Having high reflectance absorb much less amount of incoming solar energy, among which few are conducted into building and ground. Surface with lower emissivity will have higher steady-state temperature. Hot surface means it has low emissivity which cannot efficiently radiate back to atmosphere.

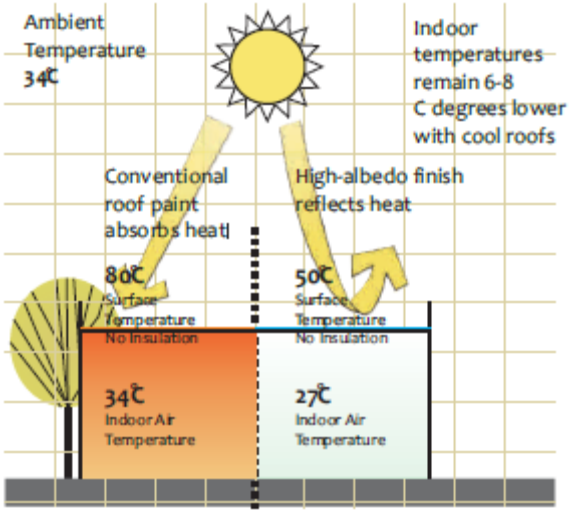


**Figure 1:** Effect of roof construction on Indoor temperature [1]

There are various passive strategies to treat the roof for thermal performance, some commonly used are:

- Green Roof
- Inverted earthen pots
- Cool Colour
- Insulation XPS
- Insulation foam
- China mosaic.

### 2.1 Aim

Identifying various cool roofs and their limitations for hot climatic region, considering their thermal performance and economy.

### 2.2 Objective

- Understanding various cool roofs with respect to its thermal performance and cost effectiveness.
- Study materials and technology regarding cost.


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### 2.3 Scope

- Study will involve the limitations which will wisely allow making decisions regarding techniques to be practiced in a particular area.
- It will improvise decision making for the selection of most effective and appropriate cool roof in hot climatic region.

### 2.4 Limitations

- The research is carried out for limiting the scope for thermal calculations.
- The research will be limited to software calculations as the conditions are not suitable for onsite readings.
- Research does not include other factors like man power, skilled labour, availability, maintenance etc.

## 2. Methodology

- Understanding various cool roofs by virtue of literature review.
- Case study & literature review are accomplished respective of hot climate, to study the material of various cool roofs.
- Cost of different roofs are reviewed by analyzing case study.
- Thermal Performance of different roofs is analyzed with the help of manual calculations done by previous researchers.
- Comparison of distinct cool roof is done based on their thermal performance, limitations, usability, cost and maintenance.

## 3. Literature Review

### 3.1 Heat transfer modes

There are three modes of heat transfer: conduction, convection and radiation.

- **Conduction:** This occurs at molecular level when a temperature gradient exists in a medium, which can be solid or fluid. Heat is transferred along that temperature gradient by conduction. [2]
- **Convection:** Happens in fluids in one of two mechanisms: random molecular motion which is termed diffusion or the bilk motion of a fluid carries energy from place to place. Convection can be either forced through for example pushing the flow along the surfaces or natural as that which happens due to buoyancy forces. [2]
- **Radiation:** Occurs where heat energy is transferred by electromagnetic phenomenon, of which the sun is a particularly important source. It happens between surfaces at different temperature even if there is no medium between them as long as they face each other. [2]

**Radiation**

| | | | |
|---|---|---|---|
| Ideal 'black' body | 1.00 | Aluminium paint | 0.5 |
| White paint | 0.97 | Galvanised steel | 0.3 |
| Gloss paint | 0.9 | Stainless steel | 0.15 |
| Brick | 0.9 | Aluminium foil | 0.12 |
| Rusted steel | 0.8 | Polished copper | 0.03 |
| | | Perfect mirror | 0 |

**Figure 2:** Representative value of emission [2]

$$Q = \varepsilon \sigma F_{12} A_1 ( T_1^4 - T_2^4 ) \quad [3]$$

**Figure 3:** Illustration of electromagnetic spectrum

**Conduction**

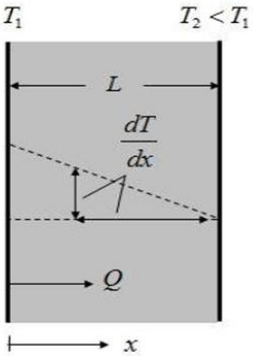


**Figure 4:** Process of conductive heat transfer and identifies the key quantities to be considered: One dimensional conduction

Q: the heat flow by conduction in x- direction (w)
A: the area through which the heat flows, normal to the x-direction (m2) dt/dx: the temperature gradient in the x-direction (K/m)
K: the thermal conductivity (W/mk) $Q = ka \frac{T_1 - T_2}{L}$

### 3.2 Literature Gap and Further Research

- Research paper does not talk about the thermal performance of various different Cool Roofs in terms of heat Gain.
- All research paper studied talks about the only advantages of different cool roofs and not about their limitations.
- No comparison seen in any of the literature regarding thermal performance, with their cost and limitations of the various cool roofs.

## 4. Data Analysis

### 4.1 Thermal Calculations of Different Cool Roof

- The climate considered for the calculation is Moderate and the city Considered is Pune.
- Area of roof for all the techniques is taken as 100 m2
- The values for Thermal Conductivity, Density, Specific Heat is taken, [7] and [8]

#### 4.1.1 Comparison on Thermal Performance of Various Cool Roofs

- Parameters for comparative analysis of Thermal Performance are R-Value, U-Value, Surface Conductance, and Thermal Capacity.[7]&[8]


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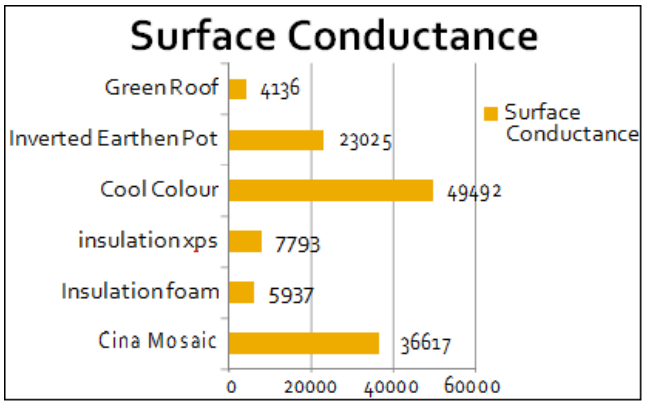
**Analysis**

**Table 1:** Comparison of Various Thermal Parameters of Different Cool Roof

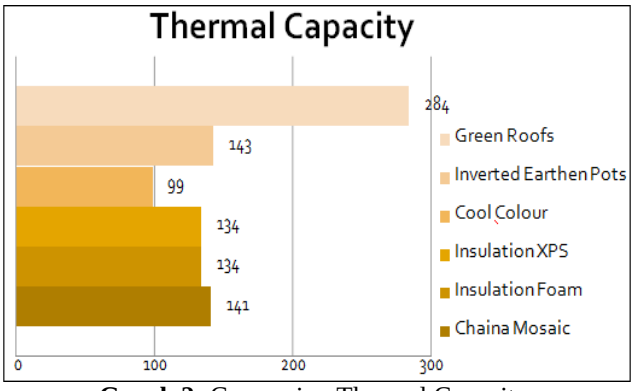
| Cool Roofs | U - Value (W/sq.m degC) | R - Value (sq.m degC/W) | Surface Conductance (W/sq.mdeg C) | Thermal Capacity (Wh/deg C) | Cost (per sq.ft.) |
|---|---|---|---|---|---|
| Green Roof | 0.27 | 3.71 | 4136 | 284 | 110 |
| Inverted Earthen Pot | 1.5 | 0.668 | 23025 | 143 | 160 |
| Cool Colour | 3.22 | 0.311 | 49492 | 99 | 25 |
| Insulation XPS | 0.51 | 1.97 | 7793 | 134 | 160 |
| Insulation foam | 0.39 | 2.58 | 5937 | 134 | 160 |
| China Mosaic | 2.32 | 0.42 | 36617 | 141 | 137 |

### 4.1.2 Comparing Surface Conductance




**Graph 1:** Comparing Surface Conductance

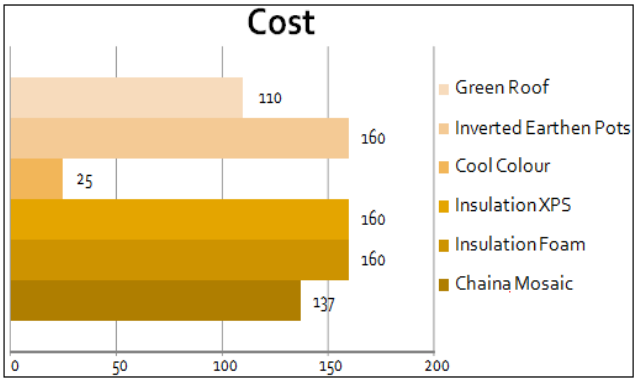
### 4.1.3 Comparing Thermal Capacity




**Graph 2:** Comparing Thermal Capacity

### 4.2 Cost Comparison

- The area considered for calculation of cost is 100 m2.
- Cost calculation is based on technology demonstration on a terrace of area 100 Sq.m (1,076 Sq.ft.).
- All rates are market rates or as per Schedule of Rates.




**Graph 3:** Comparison of Cost of Different Cool roofs

## 5. Conclusion

- Comparing all the different parameters such as U-value, R –Value, Surface Conductance, and Thermal Capacity, for all Cool Roofs Green Roofs had better performance.
- The second preferred are the insulations over roof. In insulation among the two cases i.e. Polyurethane Foam & XPS, Polyurethane Foam showed better performance.
- Next followed by Inverted Earthen Pots[4], China Mosaic[5], Cool colour coating[6].
- When compared with the cost Cool Colour Coating is the cheapest option amongst all the above Cool Roofs.[6]
- The parameter which is not studied while calculating the Performance of the roof is its SRI. The Sri of Cool Colour Coat is lesser as compared to other, but it requires a detailed study regarding it which can be studied further.

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