Readers Insight

Open Journal of Science and Technology (OJST)
ISSN:
www.readersinsight.net

# Clay Roofing Tile: A Cool Roof?

Anumah Lesado[1*], Anumah John James[2]

[1]Archshel Development Ltd. Jos, Nigeria.
[2]Department of Architecture, Faculty of Environmental Sciences, University of Jos, Nigeria.

* Corresponding author: aliyuchikaji@gmail.com

**Abstract**

The aim of this study is to determine if the clay roofing tile in its natural albedo can be considered "cool" in the thermal performance through a comparison of its surface temperature to a cool coated clay tile using the exposure rack method. It begins with highlighting the expectation (from review) of the thermal performance of a cool colored tile and comparing the surface temperature (maximum, mean and minimum) of the tiles. Day and night time temperature behaviors were also compared using graphs on excel software. A python t- test of means was also carried out to determine if there was any significant difference in the performance of the materials. It was found that the performance of the clay tile in its natural albedo is a cool tile in its thermal performance. The implication of this is a cost saving strategy. However, further research is needed as a form of coating may be needed in order to enhance its life span. A non- color coat whose only function is to protect the surface of the tile. This does not in any way disregard the use of coated tiles as user preference may still tend towards non- natural clay colored tiles, its purpose is to encourage informed cheaper methods of achieving cool roof strategies.

**Keywords:** *Clay, Cool Roof, Surface Temperature, Thermal Performance.*

***ARTICLE INFORMATION***

Received: 17 February 2018
Revised: 21 June 2018
Accepted: 10 November 2018

**DOI:**
10.31580/ojst.v1i1.151



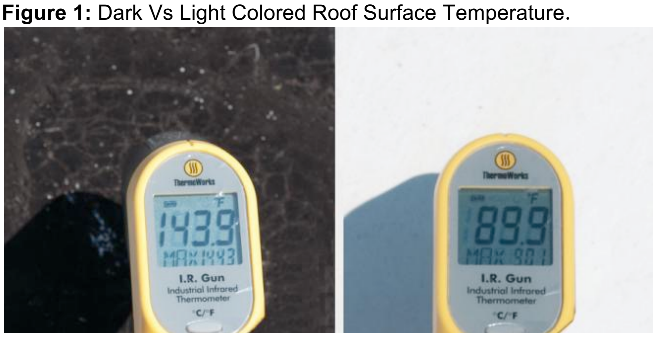
## INTRODUCTION

The urban heat island phenomenon has caused architects, engineers and contractors in the construction industry to employ passive design strategies in the design, construction and specification of buildings. These passive design strategies involve taking advantage of the environment which the building is located in order to reduce or where possible, eliminate mechanical heating or cooling. These strategies include; considerations to the building orientation, shape, envelope (choice of materials) and landscape. The increase in demand for shelter brought about by the increase in population (which is still growing), has forced architects, builders and contractors to be more careful in the specification of material choice of elements used for the building envelope. This is a passive design strategy aimed at mitigating surface temperatures of buildings in hot climates. Higher surface temperatures place increased energy demands on cooling units within the building envelope and raise ambient temperatures of their surroundings. Roofs and pavements tend to form about 60% of land cover of cities in the United States (20-25% roofs, 30-45% pavements (1) and attain high surface temperatures.

Quite a number of factors influence a materials' thermal performance but the chief determinants are; solar reflectance (albedo) and thermal emissivity. Other surface properties include; the type of coating used on the material surface, thickness and texture of the coating, its durability upon exposure to elements of weather (2). Reflectance and emissivity are expressed as fractions ranging from 0-1. The higher the value, the cooler the surface temperature the material attains when exposed to sunlight. The solar reflectance or albedo is the fraction of the solar energy that is reflected by the roof while thermal emmittance is the relative ability of the material to radiate absorbed heat energy. Generally, lighter/ brighter colors have a higher albedo as they tend to absorb less solar energy and reflect off a greater fraction to the environment (3). Darker colors tend to absorb a greater amount of solar energy and attain greater surface temperatures as shown by the image in figure 1 recording differences of up to 54$^{0}$F.

The tropical region comprises countries located between latitudes 15˚N and 15˚S with very short dry seasons. For hot- dry and hot- humid climates, about fifty percent (50%) of peak energy demand is used to satisfy space conditioning; less is consumed in cooling than heating (4). Malaysia lies in the tropical region; most of whose roofs are steep sloped owing to rainfall all year round. For the purpose of this study, we shall be discussing clay roof tile.

**Figure 1:** Dark Vs Light Colored Roof Surface Temperature.




### Thermal Performance of Clay Tiles

Owing to their suitability to the tropical climate, steep slope roofs constitute about 25% land cover area in Kuala Lumpur. Of these, 85% is of concrete tile, 10% of the clay tile while 5% is of metallic material (5). Steep slope roofs have quite a number of advantages over the low slope roofs. These include, long service life (up to 50 years), cooling by convection, minimal maintenance over the entire service years (6).

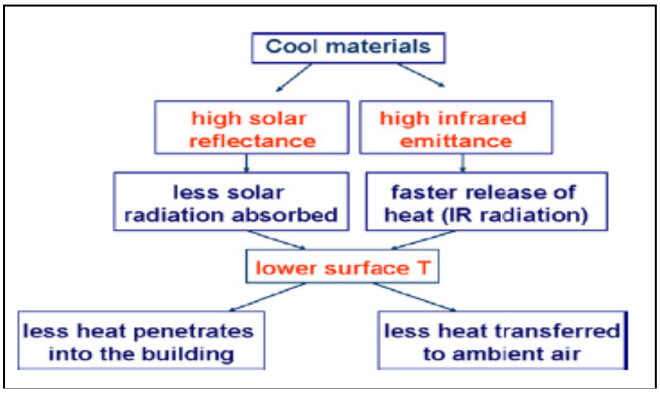
Materials used in the urban fabric absorb, store up and release heat energy raising surrounding temperatures (7). Heat absorption by urban surfaces causes surface temperatures to increase and as they increase, they radiate heat energy to their surroundings; raising ambient temperatures (8). This occurs by radiative and convective method of heat transfer. Convection occurs when there is a temperature gradient between the roof surface and ambient air. The wider the temperature gradient, the faster the rate of convection. (3) stated that with cooler surface temperatures, there is less surface- to- air heat transfer. Steep slope roofs have improved thermal performance as a result of their installation system which allows air circulation above, within and below the tiles thereby allowing heat transfer through convection (9).

Heat gain in roofs is a function of the surface properties of the material (3). Under controlled conditions, it is a measure of the surface temperature it acquires upon the incidence of solar radiation (10). Depending on the type of insulation, color and texture, emittance and mass, solar intensity and environmental conditions, roof's surface temperature can either increase or decrease (11). Lawrence Berkeley National Laboratory (LBNL) tested surface temperature of tiles and found that the materials with higher reflectance values, showed lower surface temperature values.

## Cool Roofs

Various types of cool roof technologies exist classified into; vegetative cool roof, low slope cool roofs and steep slope cool roofs. In steep slope roofs, cool roof technology is a coating that is applied to the surface of the tile to enable it to reflect a greater amount of solar energy. Surface temperature measurements demonstrated that a cool coating can reduce the concrete tile's surface temperature by 7.5°C and it can be 15°C cooler than a silver grey coating (12). The use of reflective materials on the building envelope is one of the most efficient ways to reduce the overheating of surfaces. In peak solar conditions, (about 1000 W/m²), the temperature of a black surface with solar reflectance of 0.05 can be about 50°C higher than ambient air temperature. For a white surface with solar reflectance of 0.8, the temperature rise is about 10°C. Cool roofs provide up to 28oC cooler surface temperatures under the same conditions than traditional darker roofs. Figure 2 is a diagrammatic representation of how cool roofs' surface temperature affects surrounding temperature.

**Figure 2:** Basic principle of testing how "cool" a material is (Santamouris et al., 2011)(13)




Three methods of creating cool roofing tiles are described by (7) viz; by use of clay and concrete with less elemental carbon and iron oxide to reduce absorption of solar energy, use of cool coating on the surface or mix integrally and finally, use of a highly reflective undercoat. All of these methods add cost to the production of the tile. As much as possible, passive design strategies aim at cost reduction in achieving them.

## MATERIALS AND METHODS

Thermal performance of a material is characterized by the surface temperature the material attains when exposed to solar radiation which is a function of the material's albedo and emittance (7). Lower surface temperatures of roofs mean less cooling load because less heat is transferred to the surrounding (8). Studies have shown that these values are altered after periods of exposure to environmental conditions. Tropical climates which are characterized by heavy rainfall and high solar intensity report high levels of degradation to roofing materials.

**Figure 3:** Showing the exposure rack test on the sample


An exposure rack test method was used to carry out the experiment to measure the surface temperature of the clay tile samples surface temperature using Hobo data loggers. Roof tile samples were retrieved from a roof tile company.

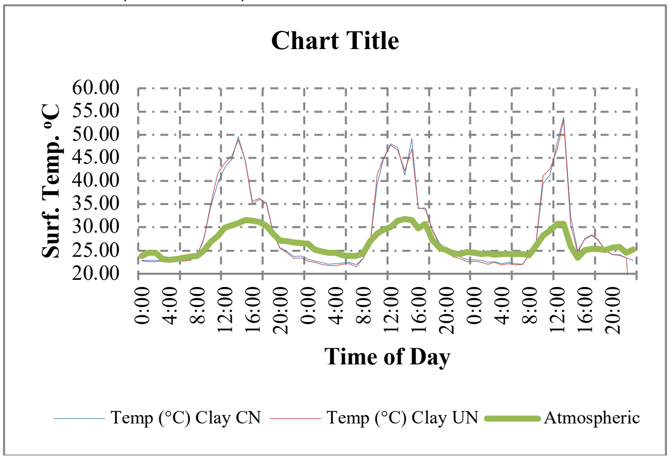
- A coated and an uncoated tile sample were used to take the readings.
- The data logger sensors were placed directly on the roof tile surface and held in place by a silver tape
- Average hourly Solar radiation data for Singapore was obtained from EnergyPlus Energy Simulation Software
- Tile samples were placed on an insulated board and placed on a wall 1.5m above the ground to ensure protection from human or animal disruption.
- Weather conditions were monitored alongside using a weather station located in the school weather station.
- Data collection was for a week however, only the three hottest days were analysed.
- Data collected within the practical periods of day time (11:00am- 6:00pm) and night time (12:00am- 8:00am) was exported to excel for proper analysis. Comparison was made of the surface temperature above atmospheric temperature.

**Table 1:** Data Analysis Criteria

| Data analysis | Interpretation |
|---|---|
| Surface temperature (maximum, mean and minimum) value | Thermal performance |
| Comparison of maximum surface temperature above atmospheric air temperature | Contribution to heating surrounding |
| P- Value of Paired Sample T-Test | If $p<0.05$, Significant difference<br>If $p> 0.05$, Insignificant difference |

FSEC (9) carried out experimental measurements of thermal properties of some steep slope roofing materials in humid tropical climate of Florida and found temperature rise of clay tile samples above air temperature to be 14.44 ºC. These values will be used as an expected surface temperature or a benchmark for the samples tested.

**Figure 4:** Surface Temperatures of Clay Tile Samples (hourly readings) CN; Coated UN; Uncoated




Single units of "Cool" Coated (Clay CN) and Uncoated (Clay UN) new clay tile samples were placed on an insulated board and surface temperature measurements were recorded for 7days. Three of the hottest days are analyzed herein. The results of the samples' temperature revealed that the "Cool" Coated (Clay CN) sample attained a warmer surface temperature than the new clay tile sample indicated in the maximum surface temperature attained during the course of the experiment (53.74°C). However, the uncoated clay tile sample (Clay UN) attained a maximum surface temperature of 53.22°C; 0.52°C cooler than the coated cool tile sample and 22.30°C warmer than the atmospheric air temperature. The performance however varied with changes in atmospheric conditions as on the third of July, the mean atmospheric temperature was 25.62˚C, the tiles showed very similar behavior with close surface temperatures. On the 5h of July however with average atmospheric temperature of 27.68˚C, the tiles showed variation in surface temperatures but behaved in a similar pattern in response to atmospheric conditions.

Daytime behavior for the samples reveals very close surface temperatures between the two samples. Slight variations are observed revealing a difference of 0.52˚C in maximum surface temperature attained of coated tile sample above the uncoated tile sample. This temperature cools to closer values with the uncoated tile sample.

Nighttime behavior of the samples show minimal variation in the temperatures they attain with variations in minimal surface temperatures cooled to 21.96˚C (CN) and 21.48˚C; differing only by 0.48˚C and yet again, the uncoated sample is cooler than the coated tile sample. For most part of the night, most tile samples cooled to below the atmospheric temperature and remained so till quite late into the morning (about 9:00am). They behave similarly; responding to atmospheric changes, dropping and gaining temperatures at virtually the same rate as can be observed in the chart. The results of the clay tile temperatures reveal a slightly altered behavior in the tile performance considered insignificant after coating. However, in order to verify, the data was run through a Python t- test to ascertain the level of significance in the difference of their performances.

**Table 2:** Result of T-Test on data samples

| Statistic | Uncoated Tile Sample | Coated Tile Sample |
|---|---|---|
| Count | 120.000000 | 120.000000 |
| Mean | 29.631333 | 29.624208 |
| Standard deviation | 8.718140 | 8.524419 |
| Minimum | 21.079000 | 21.127000 |
| 25% | 22.794000 | 22.986000 |
| 50% | 24.798500 | 25.149500 |
| 75% | 35.804000 | 35.361500 |
| Maximum | 53.221000 | 53.739000 |

The test yields a p-value of 0.9948, which means there is a 99% chance of having sample data this far apart (0.00) if the two groups tested are actually identical. If we were using a 99% confidence level we would fail to reject the null hypothesis, since the p-value is greater than the corresponding significance level of 1%. Therefore, based on the p-value of 99%, we fail to reject the null hypothesis $H_0$. Thereby accepting the null hypothesis $H_0$. There is no significant difference between the coated sample (CN) and the uncoated sample (UN). In fact, there is, based on statistical significance, no difference between CN and UN.

## CONCLUSION AND IMPLICATIONS

Passive design strategies are aimed at achieving energy and cost efficient means of maintaining thermal comfort for the built environment. Several aspects have been studied and the cool roof technology is a widely accepted solution to the problem however, cost implications can arise and saving strategies sought for best practices hence the thrust of this research. It was found that the clay tile in its natural albedo performs as cool as its counterpart coated cool tile. Long term studies (14) in the tropics have revealed that over long term exposure (20years and above), clay tile loses its original coating color and in most cases, differently colored tiles cannot be distinguished at that point. Further research could be channeled into sourcing longer lasting coatings and preservative non- colored coats can be developed to apply on clay tile for long lasting luster. For further studies, a wider range of cool color samples could be tested and testing could include reflectance and emissivity of the various products.

## References

1. Akbari H, Levinson R, Stern S. Procedure for measuring the solar reflectance of flat or curved roofing assemblies. Solar Energy. 2008;82(7):648-55.
2. Anumah JJ, Anumah, Lesado.,Benjamin, Gideon Koyan., Odoala, Micheal. The Factors Influencing Thermal Performance of Coatings on Roofing Materials. 2016.
3. Bretz S, Akbari H, Rosenfeld A. Practical Issues For Using Solar-Reflective Materials To Mitigate Urban Heat Islands
Elsevier Science Ltd. 1997;32 No. 1:95- 101.
4. Koch- Nielson H. Stay Cool. London. 2007.
5. Kiet LKK, Salleh, E., & Haw, L. C. Thermal Performance Evaluation of Roofing Systems and Materials in Malaysian Residential Development. Universiti Putra Malaysia. 2008.
6. Guyer JP. Introduction to Roofing Systems. Roofing and Waterproofing Manual, National Roofing Contractors Association: 10255 W. Higgins Road, Suite 600Rosemont, IL 60018. 2009.
7. Akbari H, Levinson, R., Miller, W., & Berdahl, P. Cool Colored Roofs to Save Energy and Improve Air Quality California Energy Commission PIER Program. 2006.
8. Akbari H, Pomerantz M, Taha H. Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas. Solar energy. 2001;70(3):295-310.
9. NRCA. National Roofing Contractors' Association (1993). 1991/ 1992 Market Study 1993 [August 20th, 2011]. Available from: http://www.nrca.net/consumer/foorsystems.aspx 10255.
10. Griggs E, Sharp T, MacDonald J. Guide for estimating differences in building heating and cooling energy due to changes in solar reflectance of a low-sloped roof. Oak Ridge, USA, Oak Ridge National Laboratory-Energy Division. 1989.
11. Palmer J. Low Slope Roof Systems. Hertfordshire,AL1 3UT: FaberMaunsell Ltd. 2003.
12. Synnefa A, Santamouris M, Akbari H. Estimating the effect of using cool coatings on energy loads and thermal comfort in residential buildings in various climatic conditions. Energy and Buildings. 2007;39(11):1167-74.
13. Santamouris M, Synnefa A, Karlessi T. Using advanced cool materials in the urban built environment to mitigate heat islands and improve thermal comfort conditions. Solar Energy. 2011;85(12):3085-102.
14. Makama L. The Effect of Long Term Exposure on Thermal Performance of Roofing Materials in Malaysian Climatic Condition: Universiti Teknologi Malaysia; 2012.