Development of a Retro-Reflective eco-friendly clay rooftile to mitigate the Urban Heat Island (UHI) effect

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Abstract*— The Urban Heat Island (UHI) effect, where the urban areas experience higher and warmer temperatures compared to surrounding rural areas is currently becoming a serious climatic phenomenon common to a lot of large cities around the world. This rise in urban temperatures lead to an increase in energy consumption of buildings and moreover, thermal discomfort to people and affects the quality of human life. There have been reported cases that this high temperature has adversely affected infants, elderly people and people with poor health conditions. Several strategies have been proposed and developed to overcome the UHI effect. This study is focused on developing a rooftile as a mitigation strategy for UHI. Sieve analysis was done and 1.18mm to 0.6mm waste glass particle size was selected as the optimum particle size for designing the reflective layer. Then rooftile was designed by applying the reflective layer, RR glass bead layer and protective sheet and Retro-reflectivity testing was done to check the RR properties of developed Rooftiles. The temperature around Wayamba Royal College, Kurunegala, Sri Lanka has been analyzed in the current study. It is located in a highly crowded area with high relative humidity and temperature. Field temperature data was collected from 15th of April to 19th of April using a pre-prepared electronic setup. The developed rooftile has reduced the surface temperature by 11.81 °C in the peak temperature hour of 11a.m to 12 noon on 19th of April. Therefore, this study explains the concept of UHI and the efficiency of RR rooftiles in mitigating the UHI effect.

I. INTRODUCTION

Predictions of the Urban Population Growth Report reveals that 66% of the World Population is expected to live in the cities by 2050 [11]. This process of Urbanization creates an increment in the building density. Natural surfaces are replaced by artificial surfaces which results in changes of thermal budget of cities paving paths to Urban Heat Island effect. The Urban Heat Island (UHI) effect is a significant environmental challenge faced by many urban areas worldwide. It is considered as one of the major problems in the 21st century posed to human beings because of urbanization and industrialization of human civilization [24]. It refers to the phenomenon where urban regions experience higher temperatures than their rural surroundings, primarily due to human activities and the extensive use of materials such as asphalt and concrete, which absorbs and retains heat. This temperature disparity can increase energy consumption, elevate greenhouse gas emissions, and degrade air quality, creating adverse impacts on human health and comfort. Efforts to mitigate the UHI effect have increasingly focused on the development and application of reflective roofing materials since heat gained through roof represents about 50-60% of the total heat gained in a building [29], while energy required for cooling purposes represents 2.9% to 6.7% of the world's energy consumption [28]. Therefore, the requirement of materials which reflect a larger portion of solar radiation to reduce the amount of heat absorbed by buildings and thereby lowering ambient urban temperatures has become an urgent need. Among these materials, clay roof tiles have gained attention due to their durability, aesthetic appeal, low cost and eco-friendly aspects. However, conventional clay tiles often lack the high reflectivity ability necessary to significantly counteract the UHI effect. This research aims to design and develop a highly reflective, eco-friendly clay rooftile using a suitable aggregate to effectively reduce the Urban Heat Island (UHI) effect in urban areas.

II. Literature

A. Urban Heat Island (UHI) Effect

Urbanization and Industrialization helps us to improve our lives and comfort, but also induce many problems to human beings, such as Global warming, Industrial waste and Air pollution. Apart from those adverse global impacts, they affect regional urban areas more seriously and directly where industrial activities and heavy use of synthetic construction material are commonly observed. This has affected to the loss of necessary balance between the natural environment and ecology. A major phenomenon was observed in large cities when compared to its surroundings; a higher temperature or heat content called Urban Heat Island (UHI) effect. The UHI effect is a phenomenon in which a significant difference in temperature can be observed between a city and its surrounding rural areas, or between different parts of a city [35]. It is widely recognized as a heat accumulation phenomenon, which is the most obvious characteristic of urban climate caused by urban construction and human being activities [23]. In early 19th century, scholar Lake Howard firstly measured and discussed UHI effect when studying urban climate in London, England [21]. Since then, much research have been conducted deeply in the characteristics of the UHI effect [1], [30], [2] and studies have found that there is a close relationship of UHI effect with the urban heat release, structure and properties of the underlying surface, population density, vegetation cover and weather conditions.

The reason for higher urban heat is mainly due to the anthropogenic heat released from vehicles, power plants, air conditioners and other heat sources, and due to the heat stored and re-radiated by massive and complex urban structures. Due to usage of massive construction materials and decreased sky view factor, large quantities of solar radiations are mainly stored and re-radiated in urban areas [31]. Urban areas also possess less vegetation, due to typical land usage. Another main problem which reduces convective heat removal is the high roughness structures present in urban areas. Therefore, as a solution for these, it has been suggested to make proper design changes such as the use of high albedo, cooler roofs, suitable building materials and proper design changes to reduce high heat intensity.

B. Mitigation of Urban Heat Islands

It was found out that numerous studies have identified effective strategies for mitigating Urban Heat Island (UHI) effects, offering substantial, financial and environmental benefits. These measures can be broadly categorized into three main types: (1) Reducing anthropogenic heat emissions, such as turning off air conditioners, (2) Improving roof designs such as installing green roofs, using roof spray cooling, or reflective roofing materials, and (3) Other design enhancements such as increasing albedo, incorporating photovoltaic canopies, or implementing humidification. These strategies can be divided into two types as strategies which can be applicable during the design and planning stages such as sky view factor, building materials and those that can be implemented after post-design such as using high reflective paints or roof spray cooling. Among these, planting and vegetation are the most widely adopted measures, offering significant energy savings through cooling effects [36]. For instance, [33] have highlighted the energy-saving potential of vegetation in reducing area temperatures. It was found out that the parks can lower temperatures through evaporation by over 300% compared to their surroundings[32]. Research also shows mitigation strategies extend beyond vegetation. Demonstrations have showed that optimizing office building design could cut cooling energy demand by 10% through improved ventilation [25]. Reducing anthropogenic heat release has significant potential to modify daytime thermal conditions, and wider buildings are more effective than narrow, tall ones in this regard [6]. Additionally, adjusting surface albedo values can lead to temperature reductions and peak electricity savings [16]. Most of the proposed measures to mitigate Urban Heat Island (UHI) effects have been based on numerical simulations rather than practical implementation. Computer simulations have been used to demonstrate that reducing anthropogenic heat and adding vegetation to building side walls could potentially lower air temperatures by up to 1.2°C and cut building cooling energy demand by up to 40%[40]. Similarly, [38] reported through modelling planting vegetation could reduce air temperatures by 0.4 to 1.3°C and achieve up to 25% savings in building cooling energy. Also, simulations show that parks and green areas could reduce cooling loads by 10% [10]. A field study found that planting a 0.6 km² park could lower temperatures by 1.5°C and result in potential savings of 4000 kWh in just one hour on a summer day [39]. Additionally, replacing urban developments with grass and shrubland could lead to a temperature reduction of 1.6°C [37].

C. Concept of Retro-reflection

Retroreflection is a phenomenon where incident light is reflected toward its source with minimal scattering, due to the unique geometry of the reflecting surface. This is typically achieved using retroreflective elements like spherical glass beads or prismatic corner cubes, which are capable of redirecting light rays irrespective of the angle of incidence [27], [17]. The integration of retroreflective materials in building components such as clay roof tiles presents an innovative approach to mitigating the Urban Heat Island (UHI) effect by enhancing solar reflectivity and reducing surface heat gain [8], [5]

D. Glass Bead Retro-reflectivity

The main components of glass bead RR are the glass microsphere and the reflective layer. The concept here is the incident sunlight is reflected back to the incident direction using two refractions at the glass microsphere boundary and one reflection using the highly reflective layer.

For external coatings using glass beads, it was explored that three types of microspheres are applied to building tiles. These experiments demonstrated that clear barium titanate glass microspheres significantly increased reflectivity, with total reflectivity and retro reflectivity reaching 39.1% and 19%, respectively. In contrast, aluminium-coated spheres halved the total reflectivity, though adding a fluoropolymer coating could enhance retro reflectivity by 2% to 5% [7]. Further research indicated that aluminium-coated spheres substantially reduced global reflectance, while glass microspheres, especially barium titanate, achieved a reflectance of up to 50.6%. Therefore, Simple glass microspheres were recommended for an optimal performance [7]. Regarding glass bead size, retroreflective materials with beads of 0.1–0.2 mm and 3 mm diameters was used [13]. Their results showed that the smaller beads had a higher solar reflectivity of 61%, compared to 50% for the larger beads. The smaller beads also performed better in reflecting solar radiation back towards the source, especially at lower angles (10° to 60°) and symmetrically at higher angles above 60°. Solid and hollow glass beads was used, finding that solid beads achieved a reflectivity of 30%, while hollow beads only reached 5%. This reduced performance of hollow beads was attributed to the air layer inside, which increased diffuse reflectance and decreased secondary refraction efficiency [22]. In terms of refractive index, compared retroreflective materials made from glass beads and clear solid barium titanate beads. Both materials demonstrated strong retro reflectivity, with glass beads and barium titanate beads achieving 30% and 32% retro reflectivity, respectively. However, barium titanate exhibited a higher global reflectance of 39% [13]. Another research measured the directional reflectivity of glass beads with refractive indices of 1.9 and 1.5. It was found out that beads with a refractive index of 1.9 had 2 to 5 times greater retroreflective capacity than those with an index of 1.5, regardless of the reflective layer colour. In Addition, a refractive index of 1.93 provided the best effective retroreflective characteristics compared to indices of 1.50 and 2.20. Variations in refractive index affect light dispersion, influencing retroreflective efficiency [20]. They also studied the effect of bead density by using densities of 0.15 kg/m² and 0.30 kg/m². They found that materials with higher bead density exhibited greater dependence on incident angles and higher retro reflectance at smaller angles of solar radiation. Lower-density materials could not concentrate retroreflection effectively, resulting in a low retroreflective performance.

E. Capsule Retro-reflectivity

Main components of capsule RR materials are the glass microspheres, transparent resin, and the reflective layer. The incident sunray passes through two refractions at the glass microsphere boundary, two refractions on the interface between glass microsphere and transparent resin, and one reflection at the highly reflective coating.

For capsule retroreflective materials, research has primarily focused on enhancing their seasonal applicability. An increase in reflected solar energy can lead to higher heating energy consumption during winter months. As a remedy to this issue, a concept was proposed of selective retroreflection and developed a new type of retroreflective material designed to optimize energy efficiency throughout the year [15]. The designed new material utilizes the variation in solar altitude between summer and winter to adjust its reflective properties accordingly. In summer, it reflects solar radiation to reduce heat buildup, while in winter, it absorbs solar radiation to mitigate heat loss. This excellent dual functionality is achieved through a strategic arrangement of reflector and absorber coatings.

F. Prism Retro-reflectivity

The main components of prism RR are the prism cones and the reflective layer. Incident sunray is reflected through two refractions at the prism boundary and multiple reflections on the reflective layer. For prism retroreflective materials, improvements have been made mainly in two areas namely material durability and the geometric design of the triangular prisms. A Research study enhanced the durability of prism retroreflective materials by applying a high-transmission, high-strength glass covering. These experiments demonstrated that the reflectivity of these prism materials remained around 0.81, with only a very small decrease of 0.02 compared to uncoated prisms. Most Importantly, the reflectivity could be fully restored after cleaning even after 485 days, indicating that the glass covering effectively protected the prisms from environmental factors such as moisture cycles and atmospheric pollutants, thus preserving both durability and reflective performance [18]. Additionally, a study investigated the impact of symmetric and asymmetric high-index glass right triangular prisms on light reflection. Their analysis revealed that symmetric high-index glass right triangular prisms offered superior performance once compared with asymmetric ones. They also noted that technologies relying on internal reflection within prisms might not be ideal for all applications, suggesting limitations in the suitability of certain prism configurations for specific reflective needs [34].

III. Methodology

A. Collection of Raw Materials

Cullet from Bottle glass was used as the Recycled Waste Glass. Glass bottles were collected from the waste glass collection centre located at Ibbagamuwa, Kurunegala. Three different coloured glass bottles; clear white glass bottles, Amber glass bottles and Green glass bottles were collected.

Commercially available, pre-prepared clay rooftiles made from a mixture of Earthenware clay and Bangadeni clay were collected from a reputed rooftile company (Bimmal Ulu) located at Bolawatta, Dankotuwa. The dimensions of the rooftile are - 21cm x15cm x 1.5cm and Surface area - 472.5 cm2.

Retro-reflective glass beads collected from the Road Development Authority were used in this experiment. Glass beads have a diameter of 0.3 mm, Refractive index(n) of 1.5 and Sample Density of 0.3 kg/m2

B. Design and Development of Rooftile

In this study, Los Angeles Abrasion Testing(LAAT) was done only to crush the waste glass to the required size to be used in the reflective layer. Initially the collected waste glass bottles were separated according to its colour and were separately crushed using the Los Angeles Abrasion Testing machine at the Civil Engineering laboratory of The Open University of Sri Lanka, Nawala. The samples were placed in the machine with an abrasive charge consisting of 12 steel spheres and was rotated for 500 revolutions at a given speed.

In this study, Sieve analysis test was performed to collect the waste glass girt within the size range of 1.18mm to 0.60mm to be used in designing the reflective layer.

In the process of application of reflective layer, the mass retained on 0.6mm sieve of the Sieve Analysis Test was collected and used in this study to design the reflective layer. First the surface of the rooftile substrate was made dry, clean and free from loose materials, dust and other contaminants. As the next step, a formwork was prepared using regifoam sheets around the rooftile for about 1cm height. This was done in-order to pool the top surface of the rooftile using the binder easily. As the binding adhesive, Petrokem BP® Epoxy Sealer ART binder was selected since, its properties and specifications matched with the requirements of the designing prototype. After covering the drains of the rooftile using temporary regifoam strips, the binder was applied to the surface of the rooftile with a coverage thickness of 3.00mm. As the next step, Glass girt reflective layer was applied on to the rooftile surface by hand for the required height of 3.00mm and was allowed to cure for 8 hours at room temperature.

Eight-hour cured rooftile samples were then examined well and made sure that excess un-attached glass girt of the reflective layer was removed if there were any. Then another layer of binder was applied above the reflective layer and RR glass beads were applied on to it and allowed to cure for 4 hours under the room temperature. Retro-reflectivity of the samples had shown a considerable decrease after a long-term exposure (368 days) in the outdoor environment [19]. Therefore, the Retro-reflectivity had to be restored by cleaning the surface. Considering that, the surfaces of these developed glass bead RR samples were covered with a transparent sheet, which can protect the RR surface from dirt and de-gradation and increase the durability of the Retro-reflectivity of the sample. When selecting the protective sheet, the main consideration was the light and heat transmittance. In addition, water absorption, impact and shear strength parameters were considered. For this, a transparent acrylic sheet with a thickness of 3.00mm was selected.

C. Field Implementation and Measurement of temperature variations

The study area chosen for this research is a commercial building located right Infront of the Wayamba Royal College primary section. It is located in the highly urbanized Kurunegala town limit, with the coordinates of 7°29’29.68”N, 80°21’16.07”E. Kurunegala is considered as one of the highly metropolitan cities in Sri Lanka. According to Koppen-Geiger classification of climate, Sri Lanka is classified as AF: tropical Rainforest climate [26]. The area around Wayamba Royal College has high temperatures and high humidity values which causes discomfort to the students and people living around the area. The experimental setup used in this research is shown in figure 01.

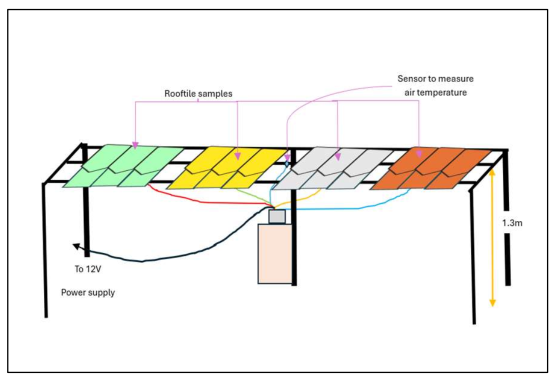

Figure 1. Experimental setup used to collect temperature readings

A separate electronic set-up was prepared for measuring the temperature readings of the prepared prototypes. It contains five DHT11 sensors, which has the ability to measure temperature and relative humidity. Four of them were used to measure the surface temperature of the rooftiles while one sensor was used to measure the ambient temperature of the surrounding. Sensors which were used to measure the surface temperature, were fixed to the bottom surface of the rooftiles and were kept in a tile rack, 1.3m above the ground surface. The single sensor which was used to measure the ambient temperature was also kept at the same height. DHT11 sensors can be used for measuring both temperature and relative humidity. But in this study, they are only used for obtaining temperature readings. These sensors contain a capacitive humidity sensor to measure relative humidity and thermistor to measure temperature readings. The Thermistor used in the DHT11 sensor is a negative temperature coefficient (NTC) thermistor and the technology here is that when the temperature increases, resistance decreases and using the variation of the resistance, temperature readings can be measured. Using this way, temperature readings were taken at every 1-minute intervals. The set-up also contains DS3231 board with a 3V CMOS battery to get the Real date and time, a microSD card module with a SD card to save the obtained temperature readings and all the components were connected to each other using an Arduino Uno.

IV. RESULTS & DISCUSSIONS

A. Sieve Analysis Test Results

In this study, the Sieve Analysis test was done with the sole intention of obtaining the waste glass particles within the range of 1.18 – 0.6 mm which was used in developing the reflective layer. A total mass of 15kg from each WG sample was used in this study. The obtained results are given in Table I.

The percent error (%) of Clear WG was 0.973, while Green WG sample gave a percent error (%) of 0.72. The percent error of Amber WG sample was 0.86. These results were well within the standard requirement of less than 1 percent so that the test was no needed to be re-conducted again.[4],[9].

Accordingly, Amber glass gave the highest particle mass (2241g) retained within the required sieve size while white glass gave the lowest mass (1964g) retained on the 0.6mm sieve size.

B. Retro-Reflectivity Test Results

The Retro-reflectivity test for building materials, such as roof tiles, measures the ability of the tiles to reflect light back toward its source. This property is crucial for applications aiming to reduce heat absorption and improve energy efficiency, especially in mitigating the Urban Heat Island (UHI) effect. The purpose of doing this test is to determine the effectiveness of Retro-reflective aggregates integrated into roof tiles and to evaluate the retroreflective performance of the designed roof tiles in redirecting light and reducing heat absorption. The device used here is called the Retro reflectometer and it emits a beam of light at a specific angle on to the material's surface. If the surface is retroreflective, it redirects most of the light back toward its source (Retro reflectometer) and a sensor on the device measures the intensity of the light reflected to the source. Figure 2 displays the results obtained through the Retro-reflectivity test.

The Retro-reflectivity test was conducted according to the BS EN 1436:2018 Standards at the Photometric & Visibility laboratory of the Research and Development Division, of the Road Development Authority.

TABLE I. SIEVE ANALYSIS RESULTS

Sieve size(mm)	**Mass Retained(g)**		
	Clear glass	***Green glass***	***Amber glass***
2.36	2820	2841	2377
2.0	2314	2417	2624
1.18	2418	2420	2530
0.6	1964	2123	2241
0.425	1521	2015	1732
0.3	1471	1127	1322
0.15	1553	1221	1354
0.075	459	421	397
0.063	157	164	143
Pan	177	143	151
Total mass	14854	14892	14871

According to the results shown in figure 1, the Plain rooftile showed the lowest Retro-reflective properties with the lowest average RR value of 22 mcd/m2/lx. The highest average RR value was shown by the yellow (Amber) glass. This was 161 mcd/m2/lx. Other than that, samples with white WG gave an average RR value of 134 mcd/m2/lx while the sample with green WG gave an average RR value of 139 mcd/m2/lx. According it is clearly seen that the average Retro-reflectivity of all designed prototypes are within the Retro-reflective range (between 100 -1000 mcd/m2/lx). All the designed specimens showed average RR values above 100 mcd/m2/lx and proved that the samples are Retro-reflective.

The type of Retro-reflective glass beads used in this study had a refractive index(n) of 1.5. Previous studies show that Retro-reflective glass beads with a high Refractive index gave high retro-reflective values when compared to ones with low refractive indices. Results of [19], shows that when the incident light reaches the glass bead RR samples with low incident angles of 10° and 30°, the sample with a reflective index of 1.9 shows a stronger RR behavior in the direction of incident light than that with a refractive index of 1.5. But due to the high cost of Retro-reflective glass beads with high refractive indices, RR glass beads with a low refractive index was used in this study.

C. Field Temperature measurements

The surface temperature of the bottom side of the conventional and designed rooftiles were measured by placing the DHT11 sensors at the bottom-centre of the rooftiles. It was made sure that the sensors were well in contact with the rooftile surface by using double tapes and masking tapes. Temperature readings were taken at

1-minute intervals from 8.00a.m to 9.00p.m every day from 15th of April to 19th of April.

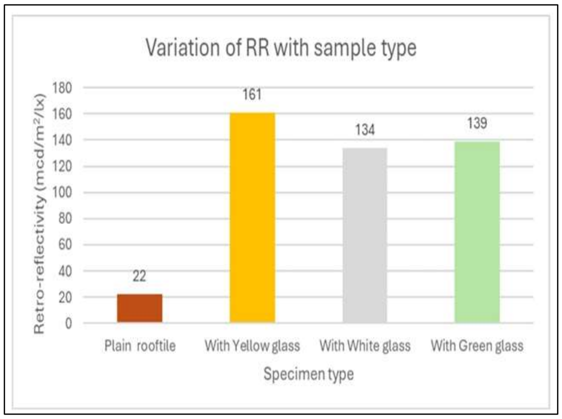

Figure 2. Variation of Retro-Reflectivity with specimen type

According to figures 3,4,5,6 and 7, it can be clearly seen that the designed prototypes have a less surface temperature compared to the conventional rooftile during the daytime. It is envisaged that they absorb less heat compared to the conventional rooftile. it is quite obvious that even though the peak ambient temperature of the day varied among 10.00a.m to 14.00p.m, the peak surface temperature was always shown during the 11.00 and 12.00 hours of the day.

From all the five days of temperature measurement, the highest overall peak temperature reduction occurred at 11.00 hours on the 19th of April with a surface temperature difference of 11.81 °C. This was shown by the White WG rooftile. These results agree with the results of [3], where the day time surface temperature of gray coloured RR surface was almost 10°C higher than that of white coloured RR surface. Also, according to [12], in a typical summer period, the surface temperature has decreased up to 12°C. Also [14] says that on a warm day, a temperature reduction of 26°C by white roof in midafternoon had occurred. The highest overall peak temperature reduction of Amber WG sample occurred on 15th of April and the temperature difference was 8.77 °C. The overall highest peak temperature reduction of Green WG sample was 4.56 °C and it had occurred on the 19th of April 2025.

But during the afternoon hours of the day (after around 16.00 hrs.), it was observed that the conventional rooftiles released heat a bit efficiently that the designed prototypes and gets cooled prior to the designed rooftiles. This can be taken as a positive factor during the Winter periods.

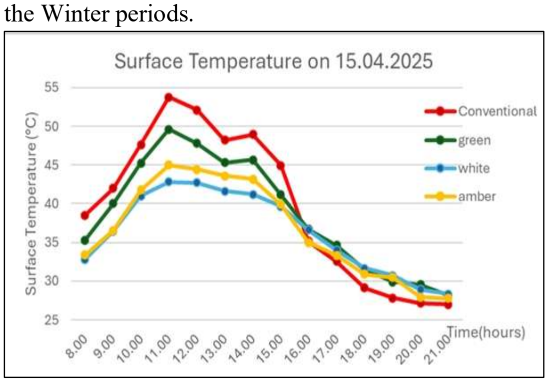

Figure 3. Surface temperature Variation on 15th April 2025 – Day 01

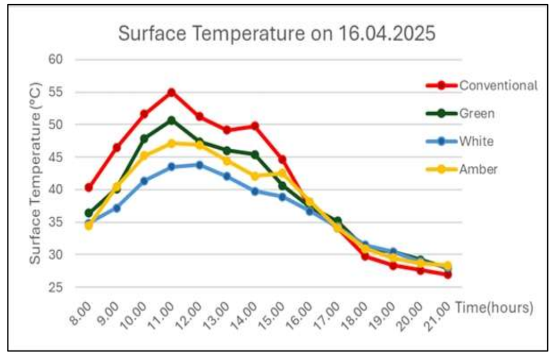

Figure 4. Surface temperature Variation on 16th April 2025 – Day 02

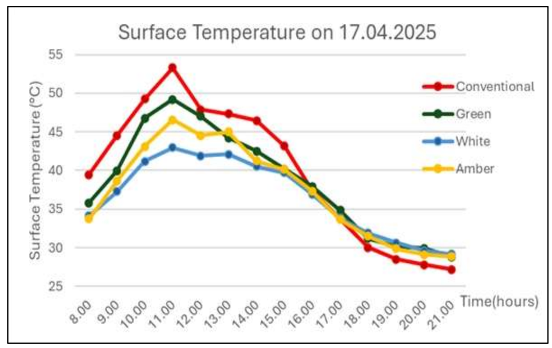

Figure 5. Surface temperature Variation on 17th April 2025 – Day 03

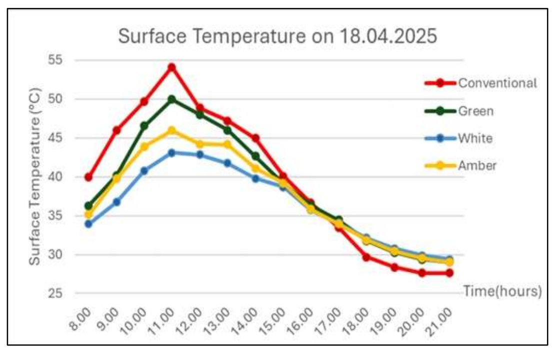

Figure 6. Surface temperature Variation on 18th April 2025 – Day 04

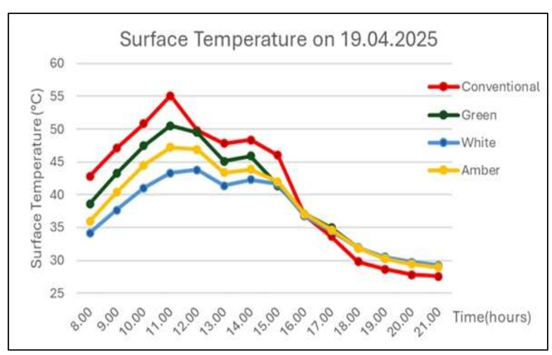

Figure 7. Surface temperature Variation on 19th April 2025 – Day 05

V. CONCLUSIONS AND RECOMMENDATIONS

The area around the Wayamba Royal College has been selected in this study as the study area for implementing and analyzing the UHI effect. The ambient temperature and the surface temperatures of the conventional and designed rooftiles were compared for a duration of five consecutive days. The results showed high agreement to the previous studies that they mitigate the UHI effect.

A. Conclusions

The Conclusions of this study are as follows,

• Retro-reflectivity values of all the samples made from the three types of waste glass were within the acceptable range; values range between 134 mcd/m2/lx to 161 mcd/m2/lx, where amber glass gave the highest RR values and as expected, conventional rooftile showed the lowest RR value.

• All samples showed lesser surface temperature values when compared with the conventional rooftile during the peak temperature hours. This proves that designed roof tile has higher thermal properties than the conventional rooftile. Consequently, mitigate the UHI effect.

• Highest surface temperature difference was shown by the White WG rooftile, with a surface temperature difference of 11.81°C on the 19th of April. This proves that white WG rooftiles are efficient than the other samples.

• When compared with the conventional rooftile, designed samples were less efficient in releasing the absorbed heat back to the surrounding.

B. Limitations

The type of Retro-reflective glass beads used in this study had a refractive index(n) of 1.5. Previous studies show that Retro-reflective glass beads with a high Refractive index gave high retro-reflective values when compared to ones with low refractive indices. But due to the high cost of Retro-reflective glass beads with high refractive indices, RR glass beads with a low refractive index was used in this study.

Even though six rooftile samples were placed in the field measurements from each sample type, only one rooftile was connected to the temperature measuring sensor from each sample. This was because of the high cost in connecting sensors to every rooftile used for taking the temperature readings. This could reduce the accuracy of the field measurements.

In measuring the temperature, DHT11 sensors were used. The accuracy of these sensors is ± 2 °C which is quite a low value. Sensor type DHT22 has an accuracy of ± 0.5 °C which is relatively a high accuracy. Due to the high cost of the DHT22 sensors, they were not used in field temperature measurements.

C. Recommendations

Due to the difficulty in taking the field temperature measurements during the late night and early morning hours, only a 13-hour simulation was done during this study. Therefore, it is recommended to carry out a complete 24-hour simulation in future studies and analyze the late night and early morning UHI effect.

This study was only conducted for a period of 05 days due to practical issues raised by the study area being a private commercial building, So, it is recommended to conduct a long-term stimulation for at least a month's period to get a clear idea about the potential to mitigate the UHI effect.

In the current study, only flat rooftiles which are small when compared to the common rooftiles are studied. This was done to minimize the difficulties in placing the waste glass and RR glass beads to the curved rooftiles and to reduce the cost in manufacturing the rooftiles. Therefore, it is recommended to further carry out studies with curved rooftiles, larger in size to identify the potential in mitigating UHI effect.

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