Use of Thermal Insulator Paving Bricks to Combat Global Warming

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1. Introduction

In urban areas, paved surfaces account for large open surface area which is susceptible to solar radiation from the sun. **In summer season**, during the day, the temperature in most cases is higher than **25°C.** For example in **Zanzibar and Dar es Salaam** cities, the temperature may rise up to even 34°C.

The radiating heat is normally absorbed by concrete and masonry elements which are the main construction materials for walls and paving slabs especially in urban streets, and parking lots, then the heat is emitted back in the surrounding air causing **Heat Island which contributes to global warming.** The above challenges call for studies on different means of reducing temperature in paved streets and buildings.

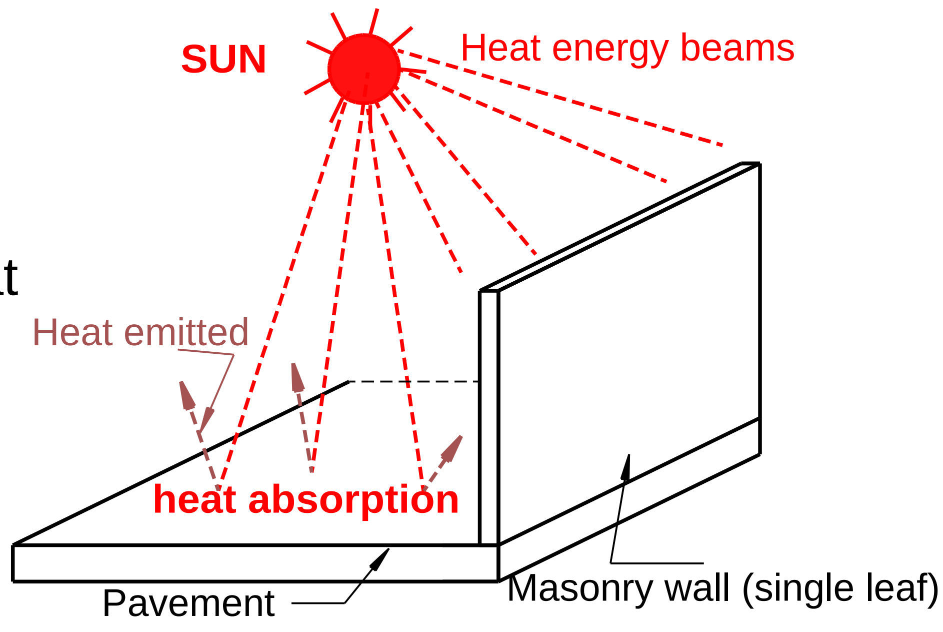


Figure 1: Heat radiation schematic

Objectives

The main objective of this study was to attempt to reduce heat absorption and to increase heat loss in paved grounds/streets by using insulated paving bricks and at the same time reduce environmental pollution by using waste materials i.e. coconut fibers. The specific objectives were twofold, namely;

- To check the suitability of thermal insulator paving bricks in terms of strength, durability and heat resistance and compare with the normal solid paving blocks;

- To investigate the heat energy reduction in city streets by using thermal insulator paving blocks;

Urban Heat Islands And Paving Bricks

Urban Heat Islands

An urban heat island (UHI), is a metropolitan area that's a lot warmer than the area surrounding it. Urban heat islands are created in densely populated and densely constructed places that have lots of activities which burdens not only the waste disposal but also control of heat generation between buildings. Nighttime temperatures in UHIs remain high because the emission of heat from the ground is trapped by the parking lots so that temperatures remain high on lower levels of the buildings. Scientists are studying to establish to which extent urban heat islands contribute to global warming. According to Sweeney et al[1], some of the mitigation measures already being practiced to control the heat island effect in urban areas include the use of green roofs and use of lighter coloured materials on building constructions.

Paving Bricks

Paving bricks in this context are those bricks that are locally manufactured, as displayed in Figure 1, to be used for paving the ground surface. They are manufactured to withstand both hot and cold temperatures, rain, pedestrian traffic as well as give access to light vehicles. Paving bricks are manufactured in conformity to the ASTM C 902 code.

Strength Requirements

Class SX; minimum compressive strength shall be **48.27 N/mm^2**

Class MX and NX; minimum compressive strength is **13.79 N/mm^2**.

Water Absorption Requirements

Class SX bricks shall absorb not more than **11%**

Class MX brick cannot absorb more than **17%**

Abrasion

Accordingly, there are three types of pavers based on the type of traffic access:

1. Type I pavers are appropriate for areas subjected to **extensive abrasion**, such as commercial driveways and entrances.
2. Type II pavers are intended for walkways and floors in restaurants and stores **(intermediate abrasion).**
3. Type III pavers are used for residential floors and patios **(low abrasion)**

Table 1: Maximum abrasion index requirement for traffic types

Traffic type	Maximum abrasion index
I	0.11
II	0.25
III	0.50

Paving Bricks

Figure 2: Paving bricks

Investigation Methodology

Materials that were utilized included Sand, Cement Type II because it is special manufactured to be used in concrete which is in touch with the ground, and

Grass to be embedded or sandwiched between two faces of paving brick to break thermal bridge to increase thermal insulator properties of paving bricks.

Coconut fibers were also added to replace sand in percentage wise so as to increase the compressive strength and thermal insulator properties of paving bricks. The size of paving bricks was 200×100×70 mm thick The general procedure in the study was as detailed below:

Most of paving bricks used in Dar es Salaam for pedestrian use and light vehicle accesses are manufactured locally using simple tools as portrayed in Figure 3.

Figure 3: (a) Mixing of materials **(b)**Compaction by tamping

Samples Preparation

Sample Type 1:
Solid paving bricks- which are traditionally manufactured for paving purposes by most vendors in Dar es Salaam. Sand and cement were mixed manually according to the specified ratio of 1:6

Sample Type 2:
The mix ratio of materials remained the same, but in this case, two layers of **grasses** were introduced in the bricks to instill the insulation property. The grasses were cut in 14 - 16 cm pieces long as portrayed in Figure 4 to allow for sufficient end cover of at least 10 mm.

Figure 4: Grasses

Sample Type 3:

The mix ratio of materials remained the same but added with **coconut fibers** or coir by percent weight in three different quantities, namely 0.5%, 1% and 1.5%. The fibrous husks were obtained from Msasani area in Dar es Salaam

Figure 5: Coir (coconut fibers)

Figure 6: Fibrous husks

Testing Of Paving Bricks

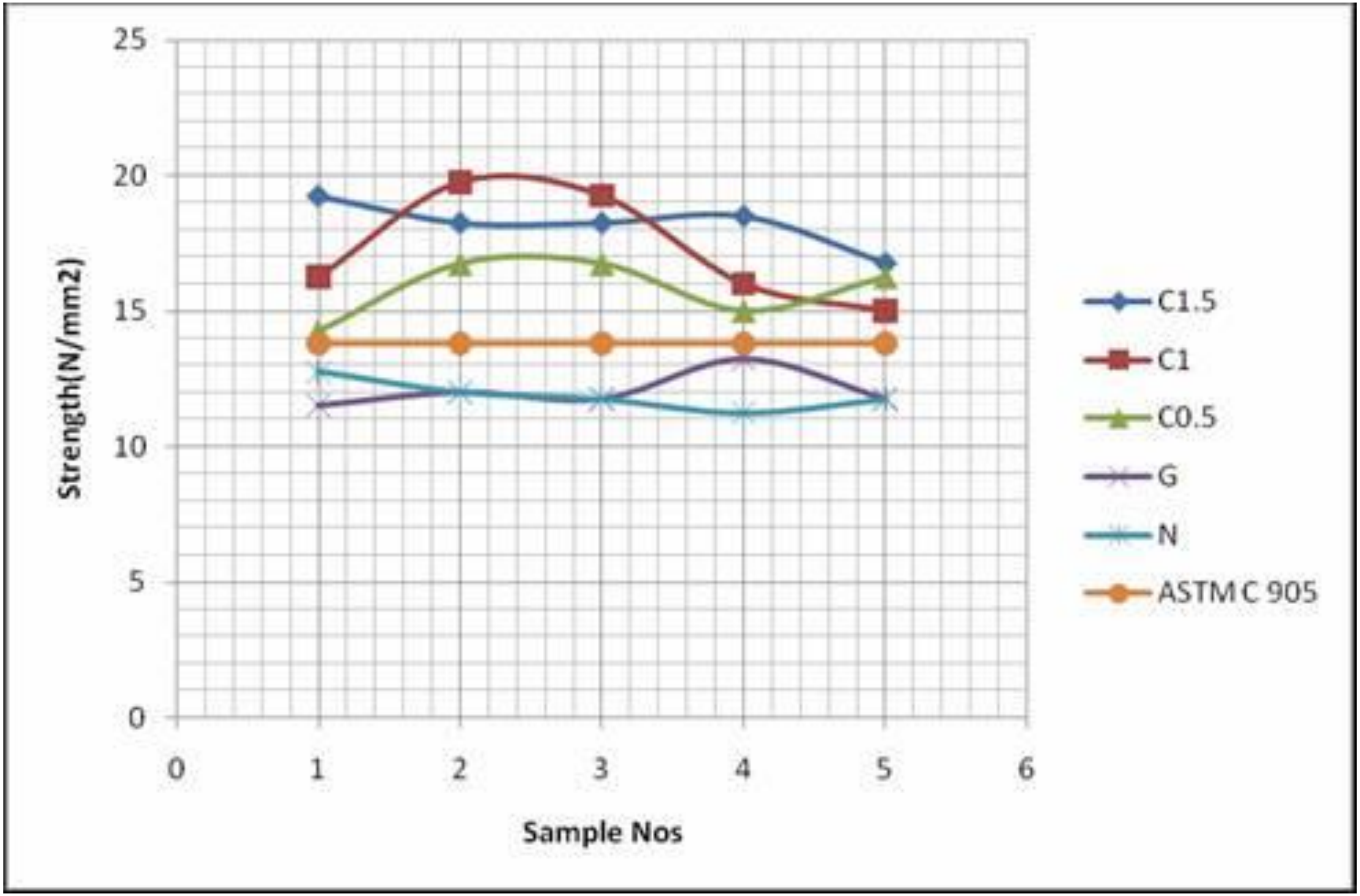
The bricks were then cured by covering them with wet sacks for 21 days, then they were left in air for 7 days after which they were tested for compressive strength, water absorption, and heat flow.

The adopted key notations in the test results and in the graphs are as detailed below:

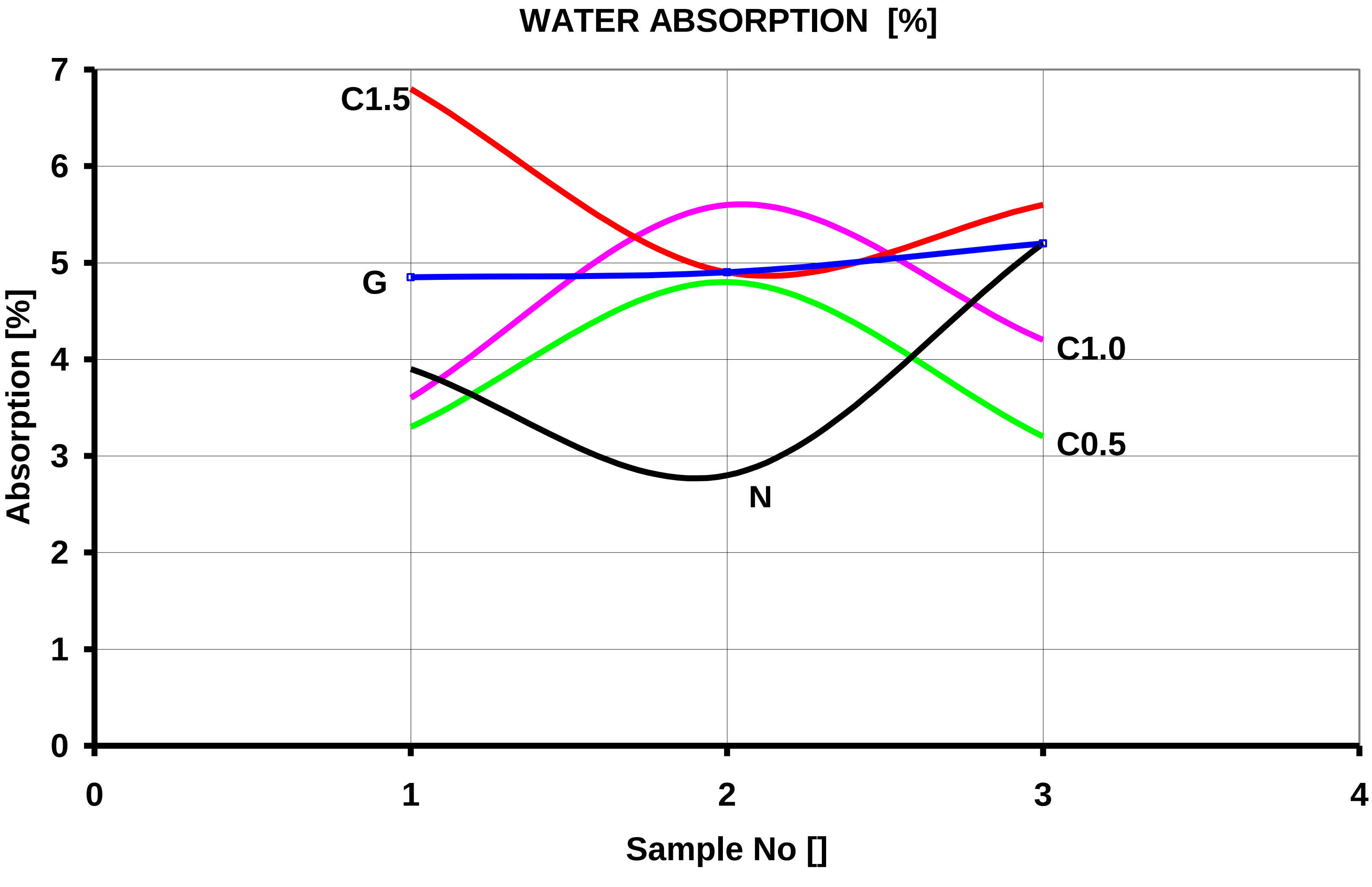
C1.5 means the sample paving bricks contain 1.5% of coir
C1.0 means the sample paving bricks contain 1.0% of coir
C0.5 means the sample paving bricks contain 0.5% of coir
G means sample of paving bricks which compose of two layers of grass
N means normal solid paving brick sample

The analysed test results are given in the following figures:

Compressive Strength Test



Water Absorption Test



Strength and Water Absorption Results

Brick samples	Average compressive strength		Average water absorption %	Maximum water absorption % ASTM C902	Calc. Abrasion Index
	N/mm^2	psi			
C1.5	18.1	2625	5.8	14	0.220
C1	17.2	2495	4.4	14	0.176
C0.5	15.6	2233	3.8	14	0.170
G	12.4	1798	3.9	14	0.217
N	12.0	1740	5.1	14	0.293

Discussion on Strength, Water Absorption and Abrasion Index

Compressive strength test

The compressive strengths of the brick pavers with grass or percentage of coir are well above the required minimum strength value.

Water absorption test

The average 24 hrs cold water absorption (porosity) of the paving bricks samples ranged between 3.8 and 5.8%, which is within the acceptable maximum limit of 8% according to ASTM C 902.

Abrasion resistance

From the compressive strength test and water absorption test results, the abrasion resistance index was calculated and found to be ranging from 0.17 to 0.30, which conforms to the maximum value of 0.50 as per ASTM C902 specifications.

Heat Flow Test

This is the test which measures the rate of heat flow in the paving bricks. The heat flow test set up was as shown in Figure 9.

The test sample bricks were subjected to controlled heat increase up to 84^{0}C maximum. The temperature was measured by using infrared thermometer at the bottom and top surfaces of brick samples and the obtained results are presented graphically in Figures 10 - 13.

Key notations to the samples in the graphs coordinates are as follows:

Sample A1 and A3 represent samples which contain 1.5% of coir
Sample B1 and B3 represent samples which contain 0.5% of coir
Sample C1 and C3 represent samples which contain grass layer
Sample D1 and D3 represent samples which contain 1.0% 0f coir
Sample A2, B2, C2 and D2 represent solid bricks which were used as controlling bricks

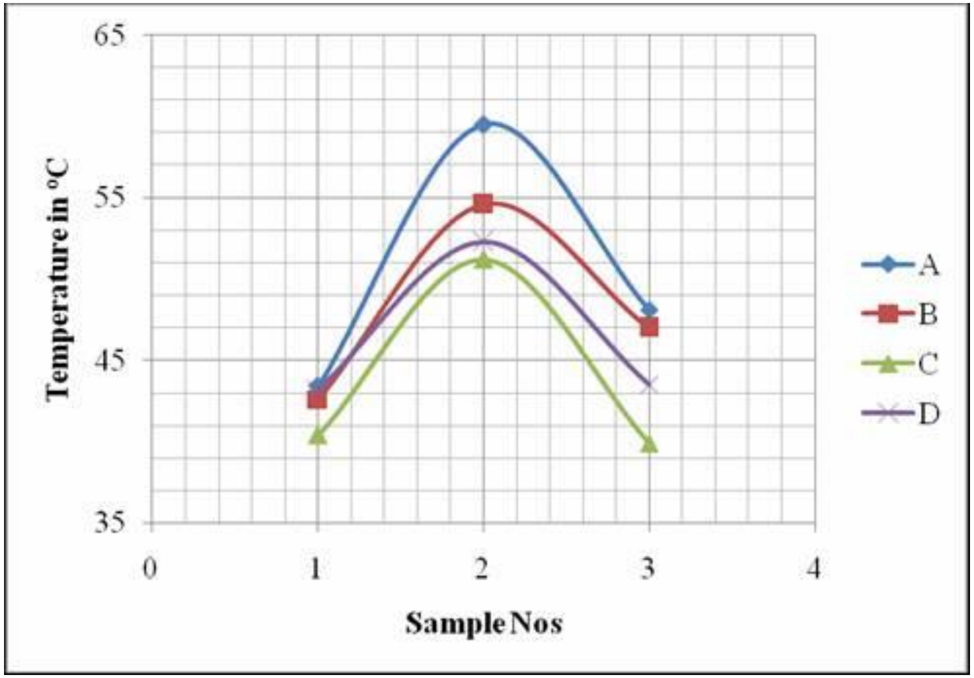


Figure 10: Temperatures recorded after 30 minutes

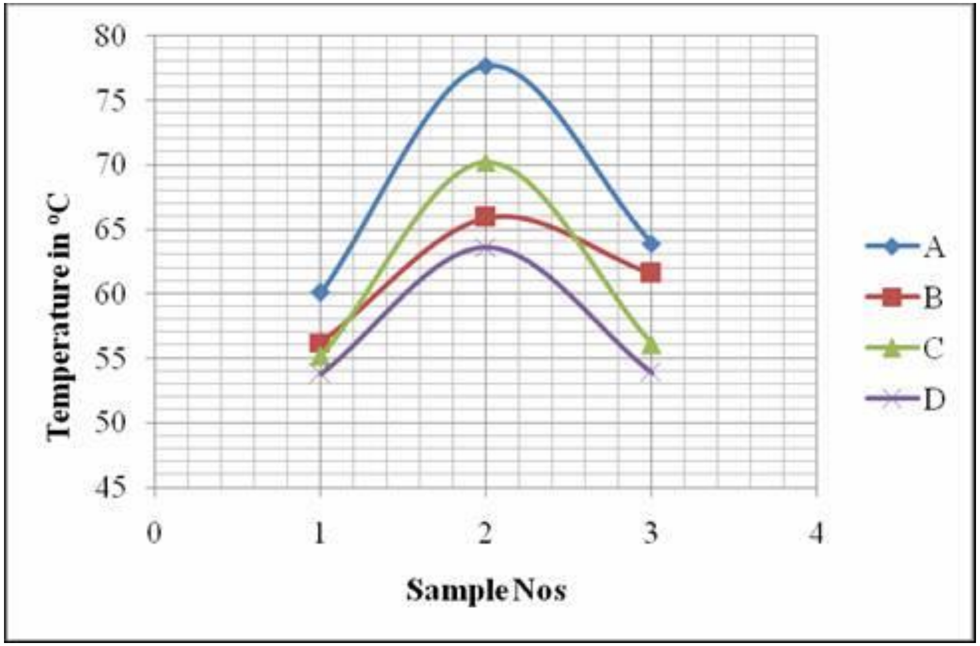


Figure 11: Temperatures recorded after 60 minutes

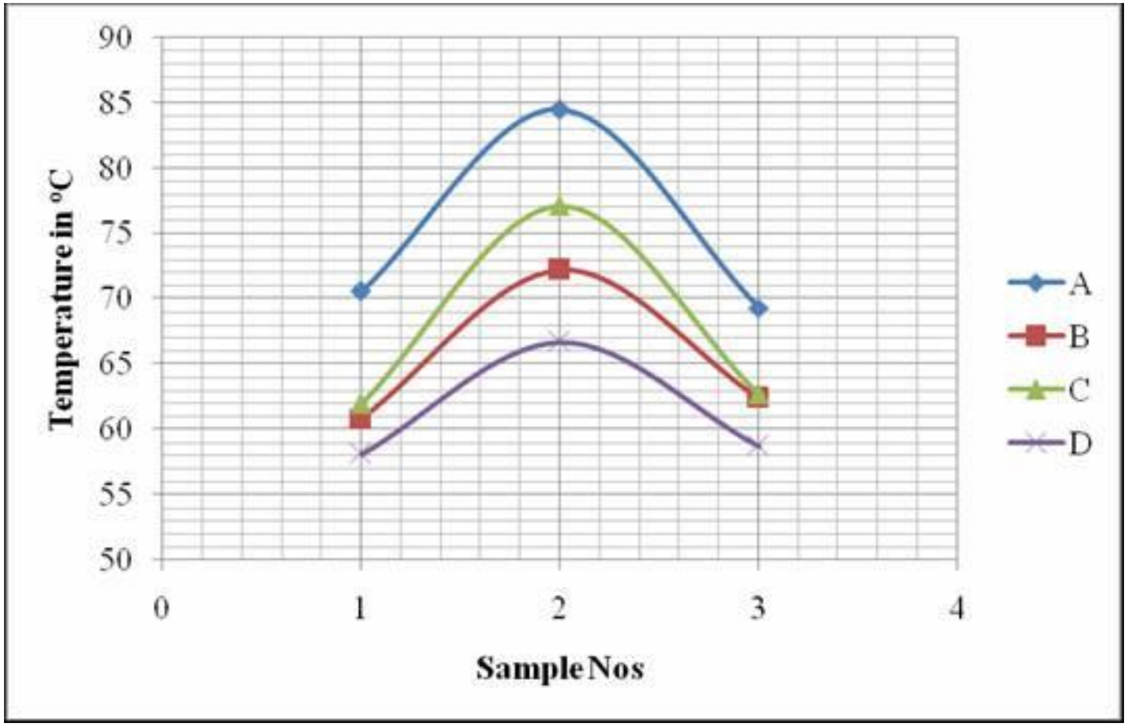


Figure 12:
Temperatures recorded after 90 minutes

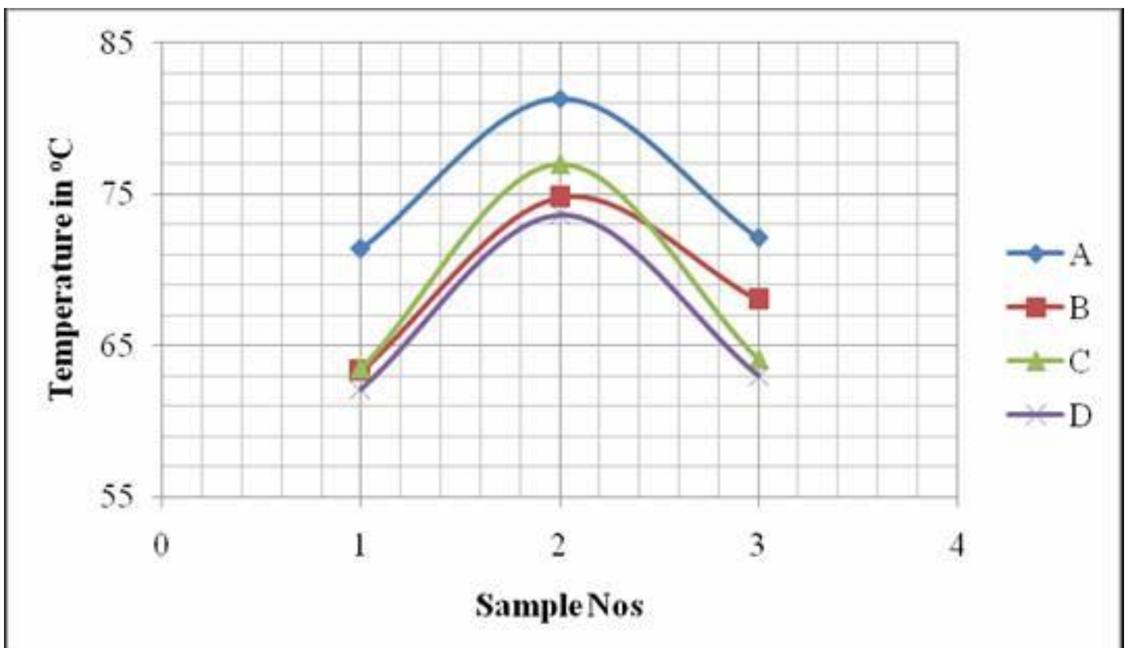


Figure 13:
Temperatures recorded after 120 minutes

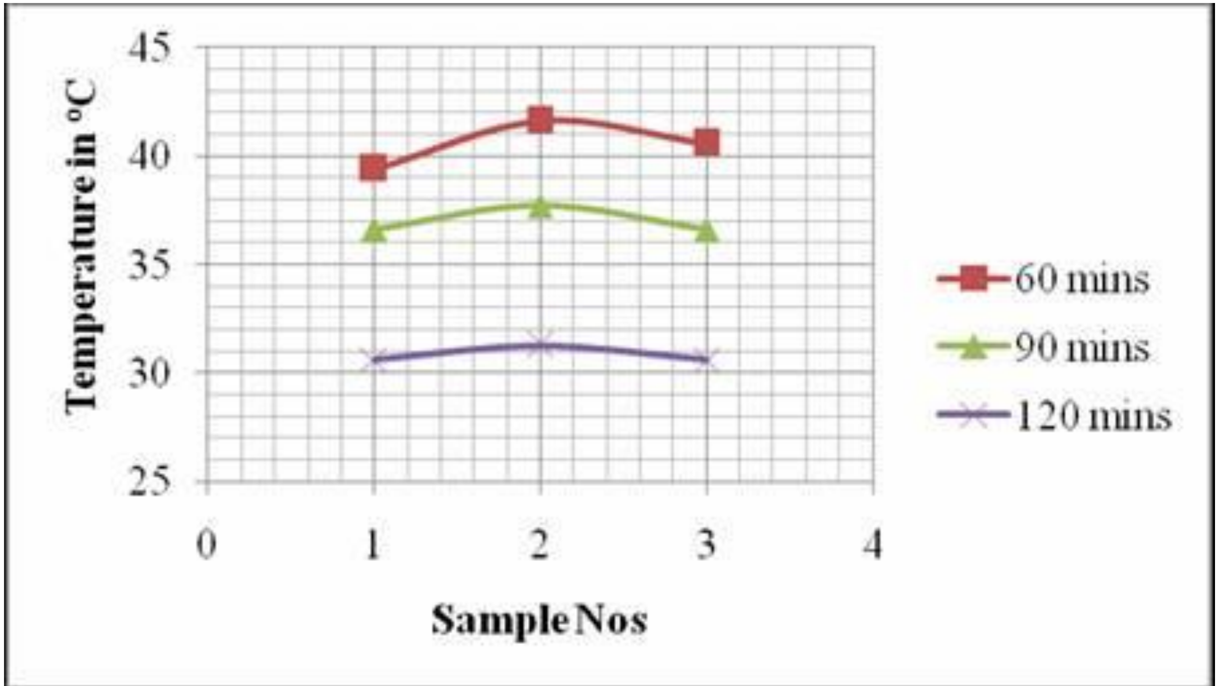


Figure 14: Cooling temperature recorded for sample bricks C1.5 and N

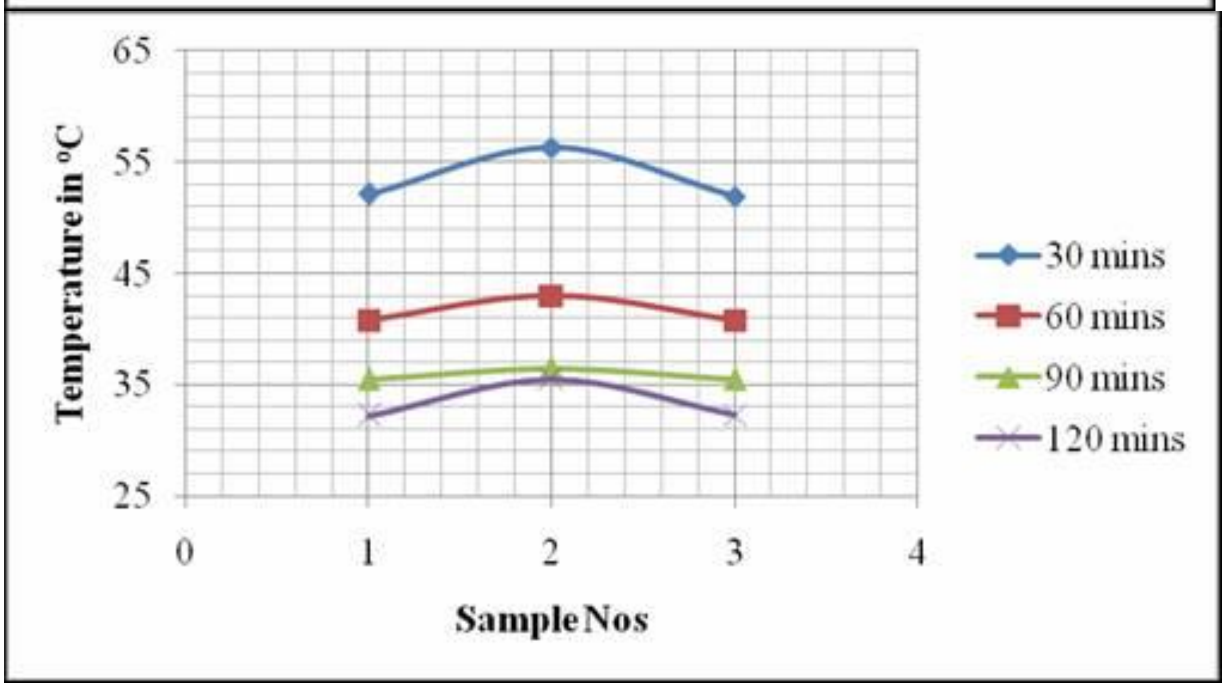


Figure 15: Cooling temperature recorded for sample bricks C1.0 and N

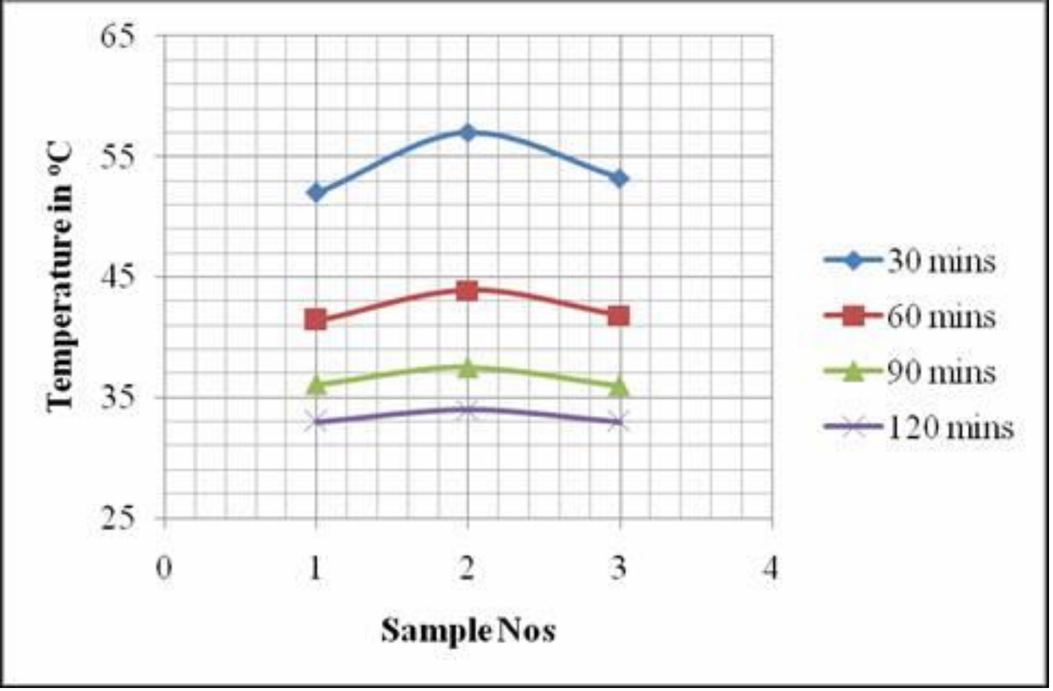


Figure 16: Cooling temperature recorded for sample bricks C0.5 and N

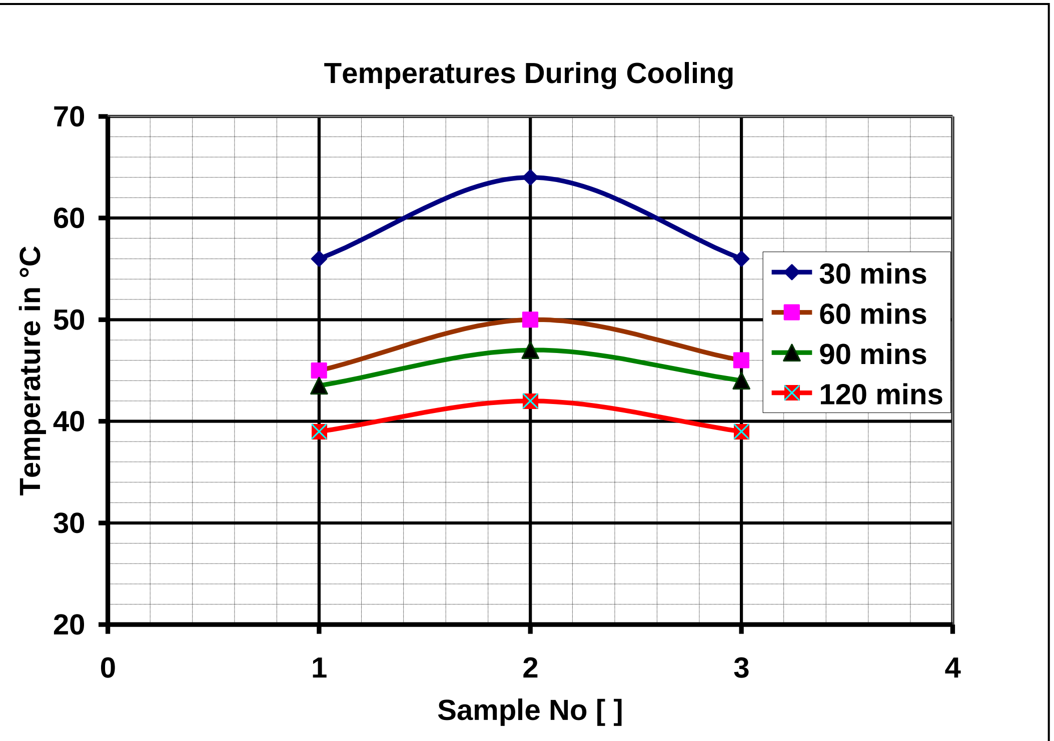


Figure 17: Cooling temperature recorded for sample bricks G and N

Discussion on Heat Flow Test Results

The aim of the test was to test the heat flow in paving bricks and the objective of the project is to reduce the amount of heat in pavements. The sample bricks which contained grass and coconut fibers show low heat flow rate compared to the normal solid paving bricks. The test results have demonstrated that the introduction of fibers and grass into bricks manufacturing creates thermal barrier to the heat flow.

During the cooling process the paving bricks which contained coir and layers of grass were losing heat faster compared to the solid paving bricks; therefore the materials can be used to produce thermal insulated paving bricks.

Concluding Remarks

Basing on the results obtained in this study, it has been established that paving bricks consisting of coir fibers 1.5%, 1.0%, 0.5% or two grass layers with a mix ratio of 1:6 for cement: sand have compressive strengths greater than the minimum required strength specified in the ASTM C 902. The water absorption, durability and abrasion index fall within the required limits so that the insulated paving bricks retain suitability of the intended purpose.

The technology used to manufacture the insulated paving bricks is more environmental friendly because it uses waste materials;

Concluding Remarks

The introduction of coir and grass layers induces insulation properties in the bricks thereby reducing thermal conductivity hence reducing the urban heat island effect;

Since the results of this study have demonstrated that the insulated paving bricks meet the standard required by ASTM C902 and at the same time effective in reducing the heat island effect they are strongly recommended for use to pave pedestrian walkways and parking lots for light vehicles.

THANK YOU VERY MUCH FOR YOUR ATTENTION