THERMAL INSULATED ACRYLIC BASED HEAT REFLECTIVE WATER PROOFING SYSTEM FOR TERRACE SLAB.

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ABSTRACT

In an RCC building, a building roof is the part which receives the highest amount of solar radiation. To provide sufficient thermal insulation, weathering course is laid over the roof slab. However, the durability of the conventional weathering courses is an issue. This study involves the development of three composite weathering courses with enhanced durability. The compressive strength and thermal insulation properties of proposed secondary roofing systems are determined as per the Indian Standards/ Procedures followed by premier research institutions. It may be concluded that the developed durable composites offer good thermal insulation and may be used in Indian conditions.

Keywords: Cool Tiles; Aerated Concrete Blocks; Light Weight Aggregate; Brick Bat Coba, Weathering Course; Thermal Insulation

I. INTRODUCTION

A building is a man-made structure with a roof and walls standing more or less permanently in one place. Reinforced concrete structures are most widely seen today. The types of structures and components of structures can be built using reinforced concrete including slabs (roofs, floors, etc.), walls, beams, columns, foundations, frames.

In good old days, when there were lots of open spaces and more windows & doors, there was good air circulation. Insulation was not really mandatory. Very often today, inadequate ventilation results in hot air getting trapped within the structure and there is no other option other than investing in air-conditioners.

Flat roofs are roof slabs that are laid horizontally and consists of an under layer and a top coat. When the rain water outlets, which have some grills, are blocked by leaves and other debris and when it rains there will be standing water. There may be a pool of water increasing or decreasing. When such is the case, that is we have a water tank literally, we should go for the same specifications as we do for an RC water tank or reservoir, lower allowable stresses, crack free, neat cement punning and all proper joints and all of the rest of it. Otherwise it behaves like a water tank. Hence, secondary roofing has to be provided to safeguard the building from the climatic conditions.

II. EXPERIMENTAL INVESTIGATION

2.1 Materials

Commercially available Portland pozzolana cement (PPC) conforming to BIS 1489-1991 [13] was used in the study. Well graded locally available river sand of nominal size less than 2.36 mm, conforming to Zone 2 and potable water were used. Two commercially available polymers were employed in the study, namely acrylic based polymer for water proofing and styrene acrylate based polymer as admixture. Both the polymers are white in color with pH of 6.2 and 6.78 respectively.

Commercially available light weight aggregates, cool tiles and clay tiles were used in the study, the properties of which, as provided by the manufacturer, are presented in Table 1 and Table 2.

Table 1. Properties of light weight aggregate (Hematite)

Property	Values
Grading Zone	II
Specific gravity	1.311
Bulk density	0.542 kg/L
Fineness modulus	1.56

Table 2. Properties of tiles

Property	Cool tiles	Clay tiles
Solar reflectance index	99%	36%
Thermal emissivity	0.935	0.75
Water absorption	3.92%	13%

2.2 Development of Weathering Courses

Three weathering courses were developed for use in the present study for comparison with conventional brickbat coba weathering course and plain unmodified roof. Figure 1 shos the schematic of the weathering courses used in the expeimental investigation.

2.2.1 Cool tiles over polymer coated terrace slab (CTPS)

This system consists of two coats of acrylic based polymer for water proofing over which cool tiles are laid.

2.2.2 Polymer modified light weight aggregate mortar over polymer coated terrace slabs (LWPS)

This consists of two coats of acrylic based polymer for water proofing followed by the polymer modified light weight aggregate mortar layer of 50mm thickness and mix ratio 1:2, comprising of light weight aggregate (hematite), portlant pozzolana cement, potable water and styrene acrylate based polymer in the dosage of 2% by weight of cement.

2.2.3 Aerocon aggregate polymer modified concrete over polymer coated terrace slabs (AAPS)

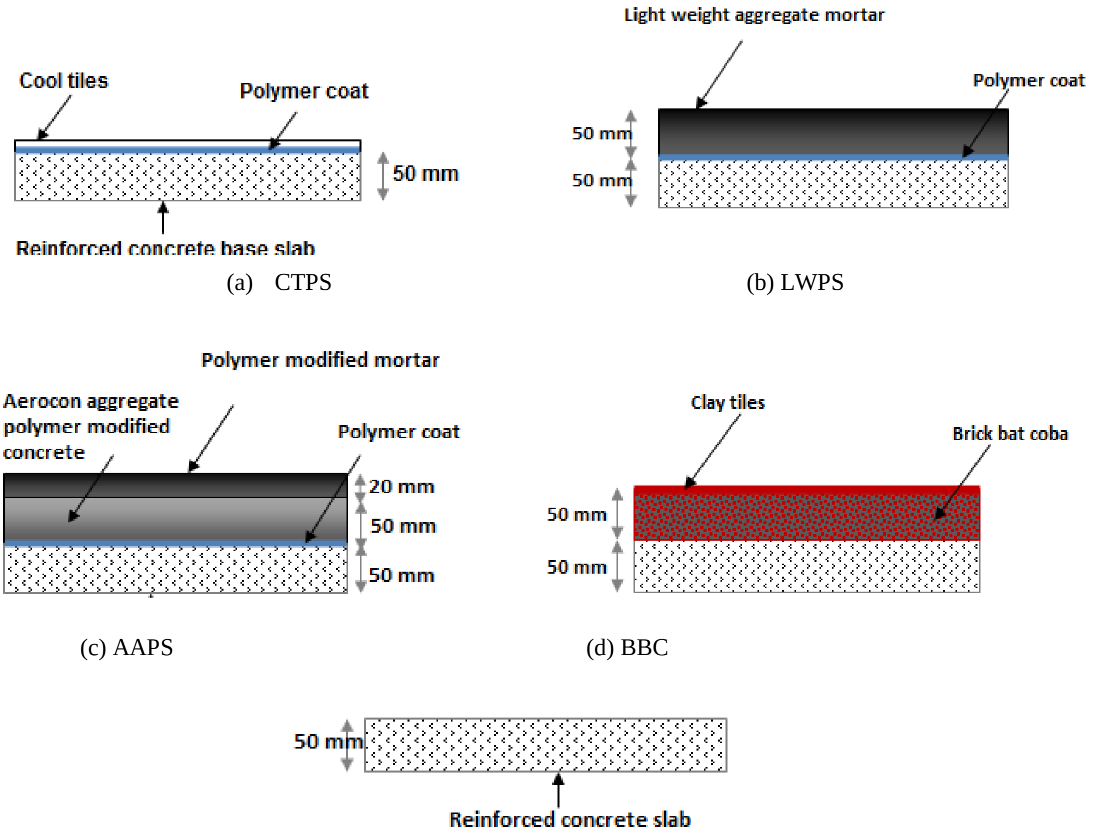
This comprises of 2 coats of acrylic based polymer for water proofing overlaid with a 50mm layer of polymer modified concrete of mix 1: 1.5 :3 with styrene acrylate based polymer in the dosage of 2% by weight of cement. Aerocon blocks broken to a nominal size less than 20mm were used as coarse aggregate. Over this, a 20m thick layer of styrene acrylate based polymer modified mortar is applied to ensure impermeability of the system.

2.2.4 Conventional brick bat coba with clay tiles (BBC)

50 mm thick layer of brick bat coba, overlaid with clay tiles, constitutes this system which is conventionally used.

2.2.5 Plain unmodified roof (PUR)

The reinforced concrete base slab is unmodified.



(a) CTPS (b) LWPS

(c) AAPS (d) BBC

(e) PUR

Figure 1. Schematic of the weathering courses used in the study

2.3 Compressive Strength of the Weathering Course

Slab specimens of size 300 mm x 300 mm were prepared for the developed weathering courses and subjected to the compressive strength test as per BIS 516-1959[1] after 28 days of curing. The test was conducted in a compression testing machine. The maximum load at which cracks propagation was observed upto the base slab was noted for each specimen. The strength of the base slab is not considered here.

2.4 Laboratory Thermal Performance Test

Slab specimens of size 300mm x 300mm were subjected to the laboratory thermal performance test. The specimens were insulated on the vertical faces and horizontal faces were left uncovered to ensure one dimensional heat flow. Halogen lamps (1000 W) were used as source of heat. A lux meter was used to monitor the intensity of heat falling on top of the specimen. Thermocouples were fixed on the top and bottom surfaces of the specimens to capture the temperature at the desired locations. The signal from the thermocouples was fed to a data logger connected to a computer. The test was terminated after the temperatures at the top and bottom reached steady state. Figure 2 shows the view of the laboratory thermal performance test in progress.

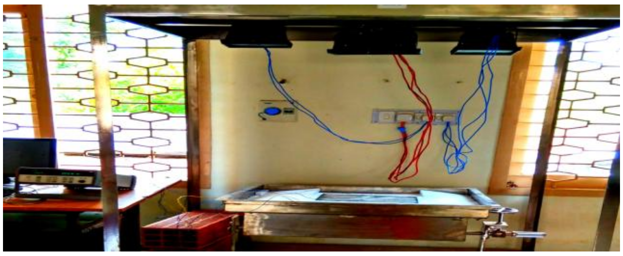


Figure 2. View of laboratory thermal test in progress

2.5 Field Thermal Performance Test

The experiments were carried out in Chennai, Tamil Nadu, 12.8757°N latitude and longitude 80.0834°E. The location is characterized by hot and humid weather. Five model buildings of identical geometry, orientation, area and climatic conditions were constructed to study the influence of each weathering course on the thermal insulation capacity of the roofing system. Figure 10 shows the view of the model buildings constructed for thermal study.

Figure 3. View of model buildings constructed for thermal study

The elimination of boundary effects on the temperature measurements was ensured by means of fixing eight uniformly spaced locations over the slab without discontinuity or joint for measurement. An infrared thermometer was used to measure the surface temperature at the top and soffit of the roofing unit at regular intervals throughout the day. Test data represents the observation made during April - May, 2015 in which the maximum and minimum temperatures recorded by the local meteorological station were 35.3^{o}C and 25.5^{o}C respectively.

III. RESULTS AND DISCUSSION

3.1 Compressive Strength Test

Table 3 shows the observation on the compressive strength test of the composites.

Type of composite	Weight (Kg/m^2)	Compressive strength of composite(N/mm^2)
PUR	122.60	
BBC	244.60	1.55
CTPS	205.00	25.34
AAPS	268.00	15.98
LWPS	233.10	1.69

The traditional weathering course, namely brick bat coba with clay tiles was found to offer a compressive strength of about 1.5 N/mm^2. Polymer modified light weight aggregate mortar was found to have a compressive strength in par with the traditional system. Aerocon aggregate polymer modified concrete showed a 9 fold enhanced compressive strength compared to the brick bat coba. The cool tiles showed better compressive strength of almost 15 times that of brick bat coba.

The weight of the composites and the contribution to dead weight was also found. The traditional weathering course, brick bat coba with clay tiles was found to have a self-weight of about 120 kg/m^2. The developed weathering courses were found to have a self-weight of about two times that of conventional brick bat coba.

3.2 Laboratory Thermal Performance Test

Concrete slabs of size 30cm x 30cm with respective weathering courses were casted and tested for its thermal conductivity. The slabs casted for the thermal conductivity determination are taken to Anna University and tested in the laboratory conditions. The slab was insulated on all sides and placed in the experimental setup. Four thermocouples, two on the upper side and two below are attached and connected to the data acquisition system. The data logger generates a chart comparing the temperature observed on all four points with respect to time. From the readings of temperature above and below the surface, the average temperature difference for each slab is determined and used in the calculation of thermal conductivity according to Fourier's law of thermal conduction.

3.2.1 Fourier's law of heat conduction

The thermal conductivity is calculated theoretically by using the Fourier's law of heat conduction as it states,

The time rate of heat conduction of a material is proportional to the negative gradient in the temperature and to the area, at right angles to the gradient, through which the heat flows.

$$Q=KA\left[\frac{dT}{dx}\right]$$

Where,

$Q \rightarrow$ intensity (W/m^2)

$K \rightarrow$ Thermal conductivity (W/mK)

$A \rightarrow$ c/s area of the specimen (m^2)

$\frac{dT}{dx}$ Temperature gradient (K/m)

3.2.2 Control Concrete

Using lux meter, incident intensity on the slab is determined. Average

Average Q = 7.92 W

A = 0.09 m^2

dT = 2 K

dx = 0.05 m

$$K = \frac{7.92}{0.3x0.3x((2.827)/0.05)}$$

Thermal conductivity of control concrete, K_{cc} = 2.2 W/mK

3.2.3 Light weight aggregate concrete:

Q= 7.92W

A = 0.09 m^2

dT = 16.14K

dx = 0.12m

$$K = \frac{7.92}{0.3x0.3x((16.14)/0.12)} = 0.65W/mk$$

Thermal conductivity of light weight aggregate concrete+ polymer modified mortar, K_{cl} = 0.65 W/mK

3.2.4 Cool tiles:

Q= 7.92W

A = 0.09 m^2

dT = 17.2K

dx = 0.09m

$$K = \frac{7.92}{0.3x0.3x((17.2)/0.09)} = 0.46W/mk$$

Thermal conductivity of cool tiles+ polymer modified mortar, K_{tiles} = 0.46 W/mK

3.2.5 Brick bat coba:

Q= 7.92W

A = 0.09 m^2

dT = 4K

dx = 0.075m

$$K = \frac{7.92}{0.3x0.3x((4)/0.075)} = 1.85W/mk$$

Thermal conductivity of Brick bat coba + clay tiles, K_{BBC} = 1.85 W/mK

3.2.6 Aerocon blocks concrete:

International Journal of Advanced Technology in Engineering and Science
Vol. No.3, Special Issue No. 01, September 2015
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Q= 7.92W

A = 0.09 m^2

dT = 13.2K

dx = 0.09m

$$K = \frac{7.92}{0.3 \times 0.3 \times ((13.2)/0.09)} = 0.6 W/mk$$

Thermal conductivity of light weight aggregate concrete+ polymer modified mortar, K_{cl} = 0.6 W/mK

The thermal conductivity of the different weathering courses were studied in the laboratory conditions and are represented graphically in the Figure 5.3. The thermal conductivity of the control concrete slab is the highest of all other weathering course composites. The lowest thermal conductivity is possessed by the roofing with cool tiles. The traditional method, Brick bat coba has more or less equal thermal conductivity of that of the control slab. The aerocon blocks and light weight aggregate roofing has a lesser thermal conductivity than the control concrete and slightly higher thermal conductivity than the cool tile roofing.

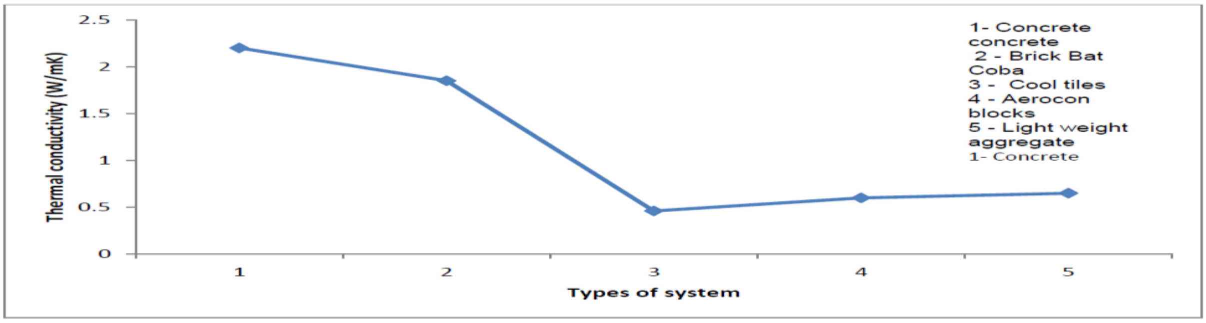

Figure 5.3: Thermal conductivity of different composites used in weathering courses

3.3 Field Thermal Performance Test

The model buildings were constructed with different weathering courses proposed in the study. The temperature above and below each weathering course was measured using infrared thermometer on all days of the hottest month of the year, May, 2015. In the month of May, 2015 the hottest day, day with moderate heat and day which was less hot were analyzed and the temperature difference observed on those days were graphically represented

Figure 4.2 Fluke Infrared thermometer

International Journal of Advanced Technology in Engineering and Science
Vol. No.3, Special Issue No. 01, September 2015
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Figure 4.3 Real time model building to observe thermal performance

in the following Figures 5.4 – 5.8. The readings were compared to understand the thermal insulation property of the particular weathering course.

Figure 5.4 shows the comparison chart of the temperature difference between the points above the roof and below the roof taken at intervals of 60 minute in the hottest day of the month. The traditional weathering course has the highest temperature recorded on the top surface of the roof slab. The cool tile roofing has shown a minimum temperature recorded above the roof slab which makes the lesser temperature inside the dwelling unit.

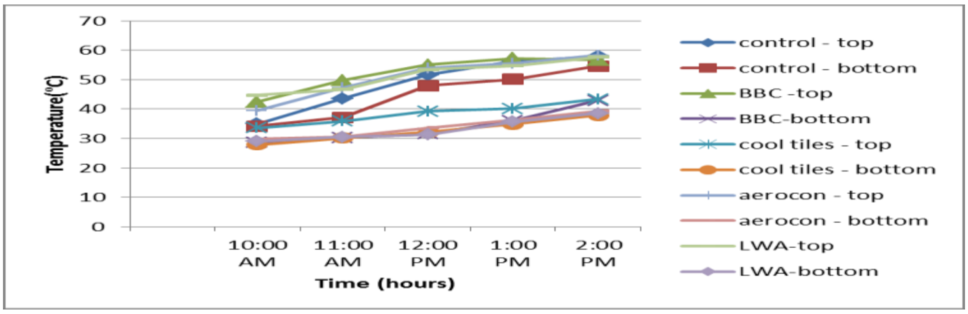

Figure 5.4: Time Vs. Temperature behavior of various weathering composites (May 27th, 2015 – hottest day of the month)

The temperature difference observed in control concrete and the traditional weathering course are compared and reported in the Figure 5.5. The temperature above the surface of the control concrete has a minimum decrease when observed below the surface of the concrete slab unmodified with the proposed weathering course. When compared to control concrete, the traditional weathering course shows a better thermal insulation.

International Journal of Advanced Technology in Engineering and Science
Vol. No.3, Special Issue No. 01, September 2015
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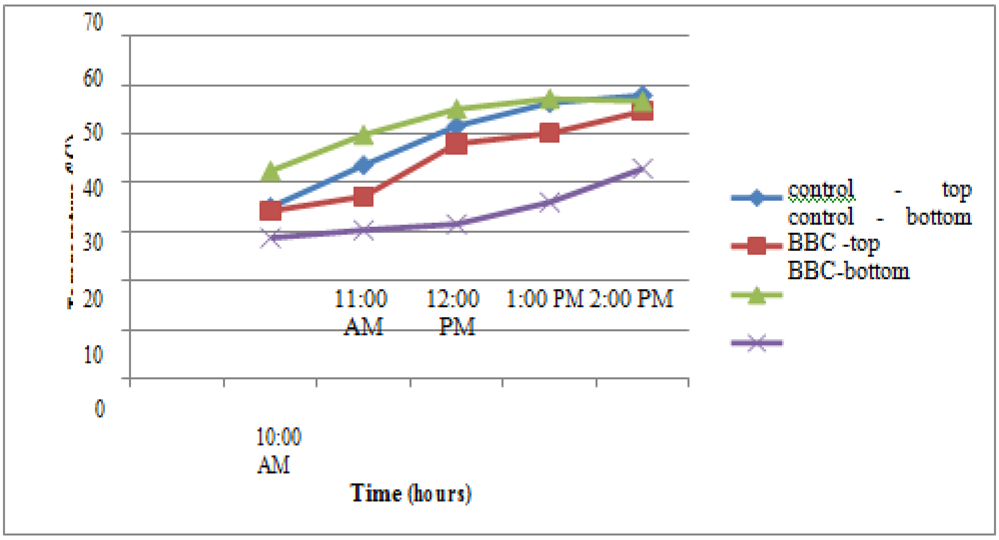

Figure 5.5: Time Vs. Temperature behavior of control and brick bat coba

The temperature difference observed in control concrete and the cool tiles are compared and reported in the figure 5.6. The temperature difference between the top and bottom of the slabs are likely similar in the control concrete slab and cool tile roofing. Whereas the temperature recorded on the top surface of the slabs are different. The cool tile roofing has observed a temperature which is almost 47% lesser than the control roofing. This proves the cool tile roofing has a netter thermal insulating property than the control concrete.

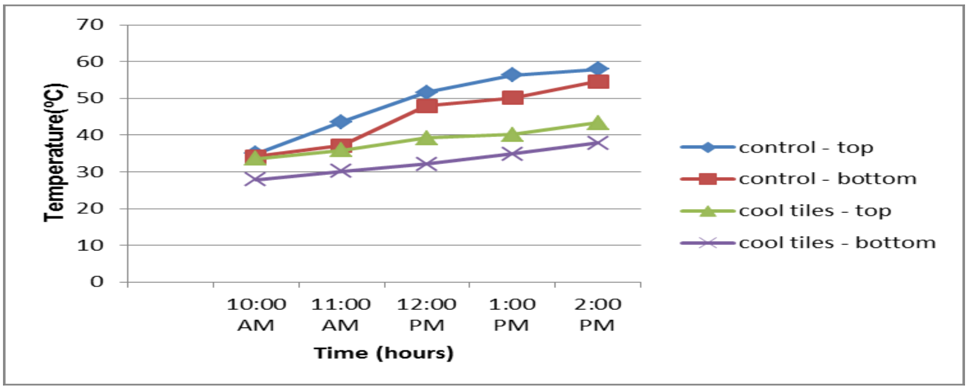

Figure 5.6: Time Vs.Temperature difference in control concrete and cool tiles

The temperature difference observed in control concrete and the aerocon block are compared and the behavior is reported in the Figure 5.7. The aerocon block roofing has shown greater decrease in temperature than the control concrete roofing. Therefore the aerocon block roofing is a better thermal insulating material than concrete. The aerocon block roofing has a temperature reduction of 80% than the control concrete roofing.

International Journal of Advanced Technology in Engineering and Science
Vol. No.3, Special Issue No. 01, September 2015
www.ijates.com
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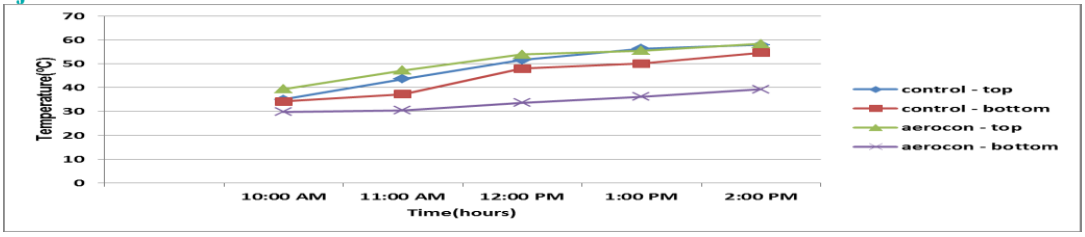

Figure 5.7: Time Vs. Temperature difference in control concrete and aerocon block

The temperature difference observed in control concrete and the light weight aggregate roofing are compared and is reported in the figure 5.8. The light weight aggregate roofing has shown greater decrease in temperature than the control concrete roofing. The light weight aggregate roofing provides a better thermal insulation than control concrete roofing. The light weight roofing has a temperature reduction of 78% than the control concrete roofing.

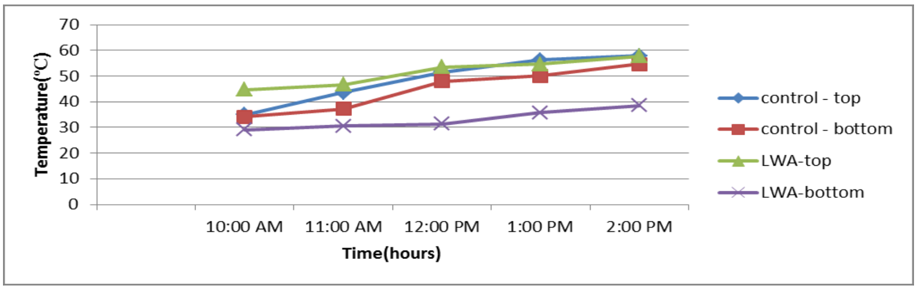

Figure 5.8: Time Vs. Temperature difference in control concrete and light weight aggregate roofing

The average temperature difference is calculated in all the weathering courses proposed in this study and are plotted in the figure 5.9. The temperature difference is a key factor for deciding the thermal insulation behavior of the corresponding weathering course. The weathering courses modified roof provides a better thermal insulation than the unmodified roof. Among all the weathering courses, light weight aggregate roofing and aerocon block roofing showed the maximum temperature reduction.

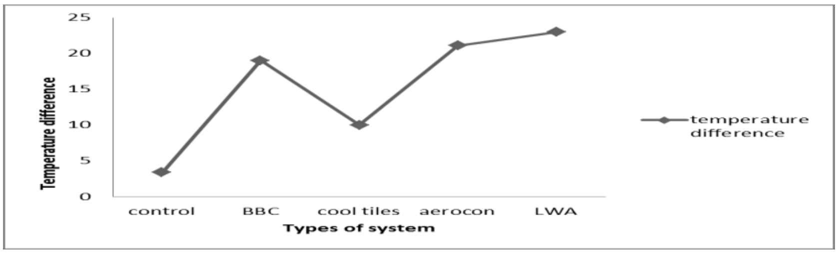

Figure 5.9: The average temperature difference of all the roofing in the study

IV. CONCLUSIONS

- Based on the investigations conducted, test results obtained and further analysis, the following conclusions are drawn.
- The terrace slab unmodified by any weathering courses, there is a reduction in temperature of 7.09% to the inhabitants.

- The conventional Brick Bat coba method of weathering course the compressive strength is less as compared to base terrace slab. The temperature reduction on average is 37.2% from the upper surface of the composite to the soffit of the mother concrete slab.
- Cool tiles laid roof shows significant reduction in incident temperature of the order of 76% as compared to unprotected roof. The surface temperature over the cool tiles also showed significant reduction than the other roofs.
- The Aerocon block concrete roofing shows an average temperature reduction of 62.45% from the upper surface of the composite to the soffit of the mother concrete slab.
- The light weight aggregate concrete roofing shows a temperature reduction of 64.35% from the upper surface of the composite to the soffit of the mother concrete slab.
- There is a definite need of laying innovative weathering course to ensure energy saving without compromising on the durability of the structure.

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