International Journal of Mechanical Engineering
ISSN : 2277-7059 Volume 4 Issue 1 (January 2014)
http://www.ijmejournal.com/ https://sites.google.com/site/journalijme/

Comparative Study of Cooling Of Small Buildings Using Different Techniques-Water Sprinkled Gunny Bags And White Roof Paint

Arshad Mehmood[1], Ayaz Mehmood[2]
[1]*(Mechanical Engineering, Zakir Husain College of Engineering & Technology/AMU/INDIA)*
[2]*(Mechanical Engineering, Mewat Engineering College/MDU/INDIA)*

Abstract:

In hot and humid region, air-conditioning is increasingly used to attain thermal comfort. Air-conditioning is highly energy intensive and it is desirable to develop alternative low-energy means to achieve comfort.

A comparison of overall cost reduction in providing thermal comfort in a building by the use of (i) Wetted roof surface and (ii) Painted roof, against bare roof surface .For this purpose M.R reading hall of M.A Library A.M.U Aligarh is chosen as the subject building and the mathematical model available in the literature have been used for prediction of roof outside surface temperature and consequent heat transmission in the building through the roof. Calculations were carried out for a typical summer day of May for Aligarh (India).

The difference between the wetted & bare roof and painted & bare roof is compared to conclude that wetted roof surface cooling technique is much better than the painted roof surface.

1. Introduction

The roof offers most of the opportunities for passive cooling of buildings, but if not performing well, it can present a huge liability to the building. On one hand, roof is the building element that is most exposed to the sky, and nearly half of the transmitted heat load of a single story building comes from the roof [1]. Justifiably, therefore, serious efforts are made to reduce this heat load by improving the roof design, on the other hand, the roof opens a wide range of possibilities for dissipating heat from the building, either by nocturnal long wave radiation to the sky or by simple convection to exterior ambient air, Air cooling is probably the most effective and potent approach for passive cooling of buildings in hot-arid regions.

Passive cooling is defined as the removal of heat of the building environment by applying the natural processes of elimination of heat to the ambient atmosphere by convection, radiation and evaporation or to the adjacent earth by conduction and convection. Roof only covers the 36.7% of total solar radiation falling on the single storied building having all four sides exposed to sun in the summer [2]. The most important passive cooling process is evaporation, which occurs to some extent whenever the vapour pressure of water in the form of droplets or wetted surface is higher than the partial pressure of the water vapour in the atmosphere. Roof evaporation technique consists of laying a thin uniform organic material lining (double layers of empty jute bags) on the roof in close contact. The gunny bags are soaked with water. The water evaporates by the heat absorbed by the roof and the air movement. The incident heat due to Sun's rays on the roof is also utilised for evaporation of the water present in the wet matting and, therefore, it cannot add to the heat content of the roof. The higher the incident radiation of the Sun and wind speed on the roof, the higher will be the quantity of water evaporated and the cooling effect. Therefore, this technique is very useful for cooling of buildings in arid areas where high solar radiation and high wind speed are available. By this technique, indoor dry bulb temperatures can be achieved near the outdoor wet bulb temperatures. The top of the roof is provided with gunny bags soaked with water, with the help of pumps.

Temperatures inside buildings and metallic sheds are much above comfort conditioning [3] in arid areas during the summer due to ambient temperatures being very high and humidity very low. Therefore, efforts have been made by considering various aspects of passive cooling design of rural houses with special reference to arid areas, viz. orientation of house, inclination and whitening of roof, thermal insulation by incorporating air pockets in the roof and necessary ventilation to button up the house during the day and open up during the night and also underground structures [4]. In arid climates, a large number of sheds with metallic roofs with masonry or metallic walls are used as farm buildings, residential buildings and industrial sheds. One typical example is also the printing sheds for textile processing units. These are so cold during the winter that printing and subsequent drying of fabric is reduced to half. The animals and human beings are also subjected to unbearably cold environment in winter and hot environment in summer. The use of electric or Diesel operated devices to moderate the environment is not feasible due to the non availability of both. Since, during winter, solar radiation is available to heat the roof and, during summer, the nocturnal sky is sufficiently cool to allow radiant cooling [5], evaporative cooling [6], painting by white paint [7] and roof pond with movable thermal insulation over the roof [8] and thermal insulation beneath the roof is used. Comparative performance of these passive techniques has been studied for cooling of metallic sheds in arid areas. The fall in roof and ambient temperature inside with different passive techniques for cooling is in increasing order with respect to thermal insulation underneath the roof, roof painted with white paint, roof provided with shallow pond with movable thermal insulation and evaporative cooling. Considering ease of operation, round the year use and the requirement of water, the shallow pond tank with movable thermal insulation over the roof has been found best for cooling of structures for better comfort conditioning in arid areas [1].

Thermal-Ply21 Elastomeric Coating (TPEC) is liquid applied, insulates itself as well as the surface it protects from weather damage, and can last 2 to 3 times longer than conventional products. Because it is liquid applied, TPEC becomes a one piece rubber like membrane roof or wall system. The temperature insulation properties unique to this coating also make it a noise insulator [9].Every exterior roof and wall system has a common enemy- the sun, whereas conventional dark-colored roofs and dark colored walls tend to absorb the sun's rays and break down due to UV degradation. TPEC can actually reflect up to 90% of the sun's heat radiation, and destructive UV rays. This heat reduction can keep the surface temperature cooler in summer than any regular coated or covered wall or roof. The reduced UV degradation allows the surface to remain highly flexible so it can tolerate the expansion and contraction (thermal shock) of the substrate without cracking, even at surface temperatures as low as -26°C. High durability translates into less maintenance, while repairs only require acrylic caulk or a roof coating touchup. All of this amounts to years or additional life for the wall or roof.

MER Corporation, a highly respected independent research and testing laboratory, tested and evaluated the TPEC roof coating system, and compared it to several other alternatives (including black tar coat, standard roof coat, and highly reflective indoor white paint). They observed that the latter is not really an acceptable roof coating, because of its poor ultraviolet (UV) stability. However, for the short duration of the test it is suitable, and provides a good measure to the near full reflectivity conditions [10].

Table1
Summary of Roof Coating Evaluation [10]

Type of Coating	Temperature Difference Per degree °F	Temperature Difference At 100° F Outside
Black Tar Coat	+0.058	+5.8
Standard White Roof Coat	-0.075	-7.5
Indoor Reflective White Paint	+0.129	-12.9
TPEC	-0.105	-10.5

As is evident from the table1, Black Tar coating results in an increased temperature on the average of +5.8° F for an outside temperature of 100° F, which is easily achieved in summer in Arizona. While standard light-color roof coating results in -7.5 degrees cooler temperature inside for an outside temperature of 100° F. For the same given outside temperature TPEC coating system results in even higher cooling effect of -10.5° F, which corresponds to 40% better performance. The highly reflective paint resulted in the best performance, but as was mentioned, this paint is for indoor use and is not suitable for roof coating because it not durable. TPEC is about 40% better than the standard light color roof paint. It has almost the same performance of highly reflective indoor paint but with superior UV stability. This performance improvement could result in significant energy saving when applied to residential or commercial enclosures.

Nomenclature

A	area, m^2
b	breadth, m
C	specific heat at constant pressure, J/kg ^{0}C
h_1	convective and radiative heat transfer coefficient, W/m^2 ^{0}C
h_c	convective heat transfer coefficient, W/m^2 ^{0}C
h_r	radiative heat transfer coefficient, W/m^2 ^{0}C
$I(t)$	hourly average solar radiation on horizontal surface, W/m^2
K	thermal conductivity, W/m^{0}C
n	number of harmonics in Fourier series, integer
$P(T)$	partial pressure of vapor at temperature T,N/m^2
R	coefficient of Eq. (13) for linear expression of partial pressure

t	time, s
T	temperature, ^{0}C
T_0	time independent part of Fourier series of temperature, ^{0}C
T_n	amplitude factor of Fourier series of temperature, ^{0}C
T_{sky}	sky temperature, ^{0}C
v	wind velocity, m/s
x	position of coordinate, m
ΔR	long wave length radiation exchange between ambient and sky, W/m^2

Greek letters

i	complex number ($\sqrt{-1}$)
α	absorptivity
α_f	coefficient in Eq. (5), m^{-1}
γ	relative humidity of air
ε	emissivity
ρ	density, kgm^{-3}
σ	Stefan–Boltzmann constant, W/m^2 ^{0}C^4
ϕ_n	phase factor of Fourier series for solair temperature
ω	frequency(=2π / time period),s^{-1}

Subscripts

a	air
f	roof
fsa	roof solair
fw	wetted roof
p	paint
n	amplitude or phase angle at nth harmonic
sa	solair
w	water

2. Mathematical Formulation:

2.1Problem identification:

In most of the cases the cooling has been proposed to be used along with the mechanical air conditioning, with the objective of reducing the load on A.C apparatus. In India power shortage is a serious problem and there is least hope of any appreciable improvement in near future and with this aspects in mind the following problem for M .Tech Dissertation work has been taken–up by the author.”Comparative Study of Cooling of Small Buildings using Different Techniques: Water Sprinkled Gunny Bags and White Roof paint”. The cooling thus provided is expected to bring down the inside temperature to near comfort value. In case the temperature reduction this way is not sufficiently low and dryness is also a problem then coupling with room Evaporative cooling is expected to definitely yield the desired results.

M.R. Reading Hall of M.A Library of A.M.U Aligarh has been chosen for modeling by simulation for determining roof temperature, and heat transfer rate which were encountered in the room in case of bare, wetted and painted roof and also compared which one of the two techniques viz wetted and painted roof is better.

2.2 Description of passive roof cooling and basic principle:

The temperature of house is primarily dependent upon the temperature of the roof and walls. A 50% of the heat load in the building is from roof only [1]. Therefore various roof treatments have been studied for comparing their effective cooling. The three cases namely; bare roof, evaporative cooling and painted roof have been considered for the present analysis. The basic principle of distribution of solar radiation and heat on the various roof-cooling systems are shown in Fig. 1a–c.The solar radiation falling on the bare roof surface (Fig. 1a) is partly reflected and partly absorbed. The absorbed radiation and surrounding heated air heat up the roof surface. This heat is lost through radiation (long wavelength) to the atmosphere and through conduction to the roof surface and heat up the room. The temperature of roof depends on the number of external parameters (solar radiation, ambient temperature, wind velocity and relative humidity) and internal parameters (absorptivity and conductivity of roof surface). With the use of wetted roof surface (Fig. 1b) more heat is lost to atmosphere due to high evaporation and results in reduction in the temperature of roof, Also by the use of white painted surface (Fig. 1c) some of the heat is lost to the atmosphere due to high reflectivity which directly result in reduction in the temperature of roof.

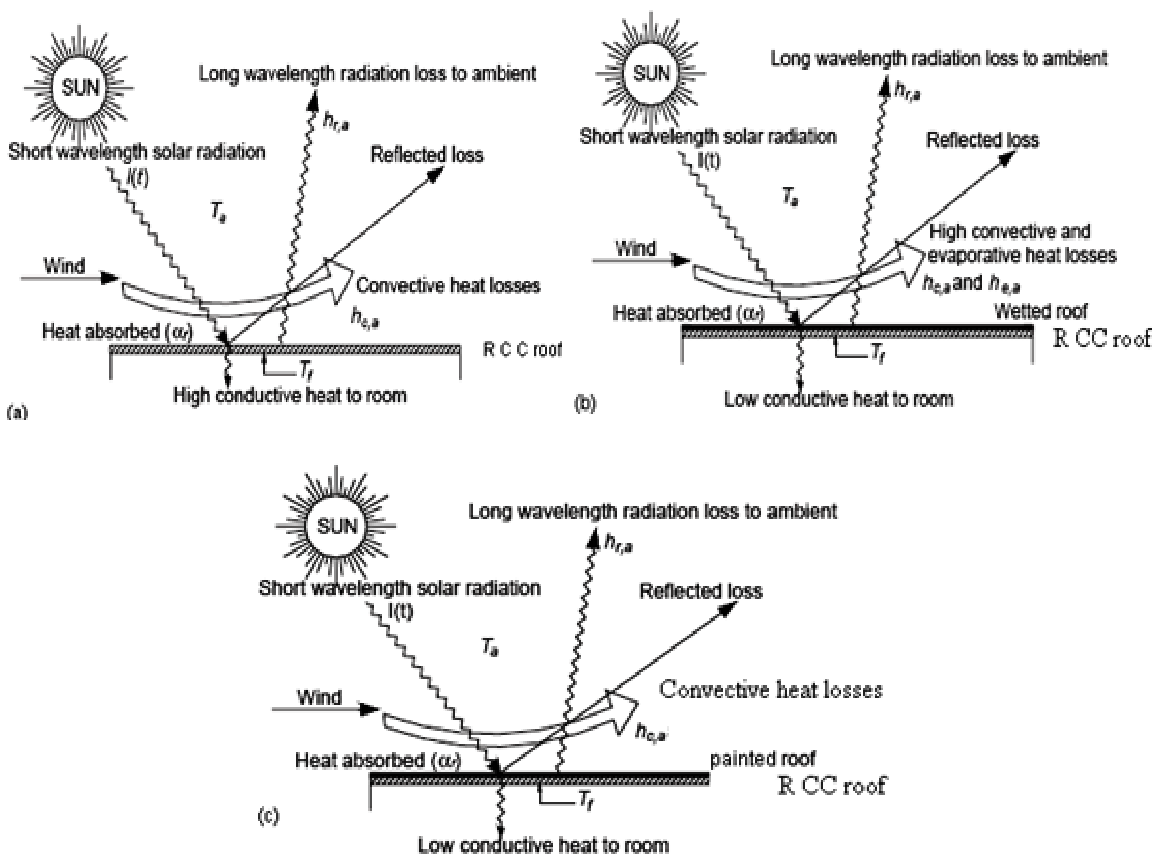


Fig.1. Basic principle of distribution of solar radiation and transfer of heat with the various passive-cooling techniques of roof: (a) bare roof without any treatment; (b) roof with evaporative cooling; (c) painted roof [11]

2.3 Thermal analysis:

To formulate the energy balance equation for roof of the hall under study, the model of [11] have been used for the present work. The following assumptions have been made:
1. Analysis is based on time dependent periodic condition.
2. Temperature distribution in the roof can be characterized by one-dimensional heat conduction equation.
3. There is no temperature gradient within the enclosure.
4. There is a uniform water layer over the roof in case of wetted roof.
6. The hall is in a steady-state condition.
7. The water and roof temperatures are almost the same owing to the thin layers.

2.3.1 Bare roof:

The energy balance equation for the bare roof surface exposed to solar radiation can be written as

$$\alpha_f I(t) = -K_f \left.\frac{\partial T_f}{\partial x}\right|_{x=0} + h_{c,a}\left(T_f\big|_{x=0} - T_a\right) + h_{r,a}\left(T_f\big|_{x=0} - T_a\right) + \varepsilon_f \Delta R \tag{1}$$

Eq. (1) can be written in the following form

$$-K_f \left.\frac{\partial T_f}{\partial x}\right|_{x=0} = \alpha_f I(t) - h_1\left(T_f\big|_{x=0} - T_a\right) - \varepsilon_f \Delta R \tag{2}$$

Where

$$h_1 = h_{c,a} + h_{r,a}$$

$$\Delta R = \sigma\left[\left(T_a + 273\right)^4 - \left(T_{sky} + 273\right)^4\right]$$

$$h_1 = 5.7 + 3.8\upsilon$$

$$h_{c,a} = 2.8 + 3.0\upsilon$$

$$T_{Sky} = T_a - 6$$

Eq. (2) can be written as

$$-K_f \left.\frac{\partial T_f}{\partial x}\right|_{x=0} = h_1\left(T_{fsa} - T_f\big|_{x=0}\right) \tag{3}$$

Where

$$T_{fsa} = \frac{\alpha_f I(t)}{h_1} + T_a - \frac{\varepsilon_f \Delta R}{h_1}$$

As the solar intensity and ambient air temperature are periodic function of time, solair temperature (T_{fsa}) for roof and roof temperature (T_f) will also be the function of time and can be expressed in Fourier series, which are as follows:

$$T_{fsa}(t) = T_{fsa,0} + \mathrm{Real}\sum_{n=1}^{n=3} T_{fsa,n} e^{-i\Phi_n} e^{in\omega t} \tag{4}$$

$$T_f(x,t) = T_{f,0} + \mathrm{Real}\sum_{n=1}^{n=3} T_{f,n} e^{-\alpha f,_n x} e^{in\omega t} \tag{5}$$

Where

$$\alpha_{f,n} = \left[\frac{n\omega\rho_f C_f}{2K_f}\right]^{1/2}(1+i)$$

Putting the values of Eqs. (4) and (5) in Eq. (3),the new equation becomes

$$K_f \sum_{n=1}^{n=3} T_{f,n}\alpha f,_n e^{-\alpha f,_n x} e^{in\omega t} = h_1\left(T_{fsa,0} + \sum_{n=1}^{n=3} T_{fsa,n} e^{-i\Phi_n} e^{in\omega t} - T_{f,0} + \sum_{n=1}^{n=3} T_{f,n} e^{-\alpha f,_n x} e^{in\omega t}\right) \tag{6}$$

Equating time independent part from Eq. (6)

$$h_1\left(T_{fsa,0} - T_{f,0}\right) = 0$$

$$T_{f,0} = T_{fsa,0} \tag{7}$$

Equating time dependent parts or equating the coefficient of $e^{in\omega t}$ from Eq. (6)

$$K_f \sum_{n=1}^{n=3} T_{f,n}\alpha f,_n e^{-\alpha f,_n x} = h_1\left(\sum_{n=1}^{n=3} T_{fsa,n} e^{-i\Phi_n} - \sum_{n=1}^{n=3} T_{f,n} e^{-\alpha f,_n x}\right) \tag{8}$$

Appling boundary condition i.e., x = 0 => $e^{-\alpha f,_n x}$ =1, and after simplifying Eq. (8) becomes

$$T_{f,n} = \frac{h_1 T_{fsa,n} e^{-i\Phi_n}}{h_1 + K_f \alpha_{f,n}} \tag{9}$$

Putting the values of $T_{f,0}$ and $T_{f,n}$ in Eq. (5), the temperature of roof surface exposed to solar radiation becomes

$$T_f(x,t) = T_{fsa,0} + \mathrm{Real}\sum_{n=1}^{n=3}\left(\frac{h_1 T_{fsa,n} e^{-i\Phi_n}}{h_1 + K_f \alpha f,_n}\right) e^{-\alpha f,_n x} e^{in\omega t} \tag{10}$$

2.3.1 Wetted roof:

Roof surface is wetted with gunny begs cloth and a continuous supply of water is assured to keep the surface wet. The energy balance equation for the wetted roof surface [12] can be written as

$$\alpha_{fw} I(t) = -K_f \left.\frac{\partial T_f}{\partial x}\right|_{x=0} + h_1(T_f|_{x=0} - T_a) + 0.016 h_{c,a}\left[P\left(T_f|_{x=0}\right) - \gamma_a P\left(T_a\right)\right] + \varepsilon_{fw}\Delta R \tag{11}$$

The partial vapor pressure has an exponential relationship [59] with temperature as

$$P(T) = \exp\left[25.317 - \frac{5144}{T + 273.15}\right] \tag{12}$$

It is too complex to solve the Eq. (11). Therefore, the partial vapor pressure can be put into a linear expression for the small range of temperature between 20 ^{0}C and 45 ^{0}C as

$$P(T) = R_1 T + R_2 \tag{13}$$

Eq. (11) can be re-written by replacing the expression of partial vapor as

$$-K_f \left.\frac{\partial T_f}{\partial x}\right|_{x=0} = \alpha_{fW} I(t) - h_1(T_f|_{x=0} - T_a) - 0.016h_{c,a}\left[R_1 T_f|_{x=0} + R_2 - \gamma_a\left(R_1 T_a + R_2\right)\right] - \varepsilon_{fw}\Delta R \quad (14)$$

Eq. (14) can be simplified in the following form

$$-K_f \left.\frac{\partial T_f}{\partial x}\right|_{x=0} = \left(h_1 + 0.016h_{c,a}R_1\right)\left(T_{fw,sa} - T_f|_{x=0}\right) \quad (15)$$

where

$$T_{fw,sa} = \frac{\alpha_{fW} I(t)}{h_1 + 0.016h_{c,a}R_1} + \frac{h_1 + 0.016h_{c,a}\gamma_a R_1}{h_1 + 0.016h_{c,a}R_1} T_a - \frac{0.016h_{c,a}R_2\left(1-\gamma_a\right) + \varepsilon_{fw}\Delta R}{h_1 + 0.016h_{c,a}R_1}$$

Now Eq. (15) is the similar of Eq. (3) and can be expressed in Fourier series simplified for the roof temperature similar as Eq. (10).

3.3.3 Painted roof

The energy balance equations for the painted roof surface exposed to solar radiation are same as bare roof surface.

3 Computational Procedures:

Numerical calculations have been performed corresponding to the hourly variation of solar radiation and ambient air temperature on the typical summer day (May) of Aligarh (latitude $27^0$53N'; longitude $78^0$04E', altitude 187m) with the help of the model of [11] and computer program prepared in FORTRAN 95. Hourly solar intensity and ambient air temperature used in solving the model are given in Fig 2.

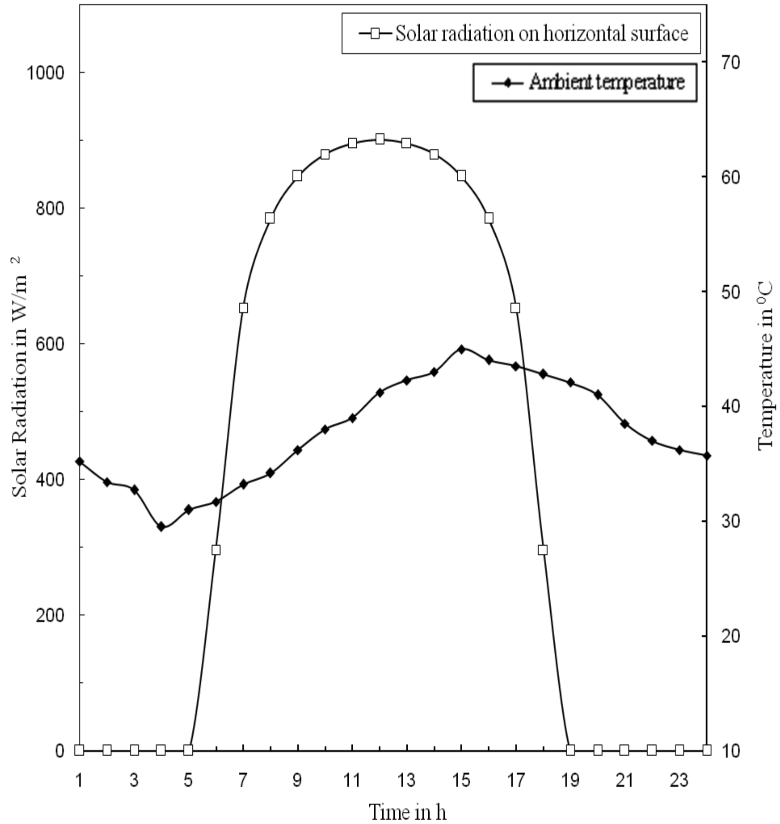


Fig2. Diurnal variation of solar radiation and ambient air temperature of typical day of summer (May) at Aligarh used as input parameters

The hourly variation of roof temperature for each technique of passive cooling was computed by using the hourly solair temperatures for the particular surface. The values of input and roof parameters used in computation have been given in Table 1.

Table 1

Input parameters used for computation

Parameters	Values
A_f	266.72 m^2
b_f	8.839 m
ρ_f	2000 Kg/m^3
C_f	880 J/Kg-^0C
K_f	1.37 W/m -^0C

α_f	0.75
ε_f	0.63
ε_{fw} , α_{fw}	0.6
ε_p , α_p	0.1
v	5 m/s
γ_a	0.15
R_1	283.81
R_2	-3291.09
σ	$5.67*10^{-8}$ W/m^2- $^0C^4$

Expansion of Fourier series has been applied for the periodic analysis [13]. Fourier coefficients were obtained by using the hourly data of solar radiation, ambient air temperature and solair temperature. Fourier coefficients for solair temperature of different roof surface and time dependent overall heat loss coefficient are given in Table 2. Only three harmonic were considered in all the expression, since first three harmonics are sufficient to reproduce the original function [14].

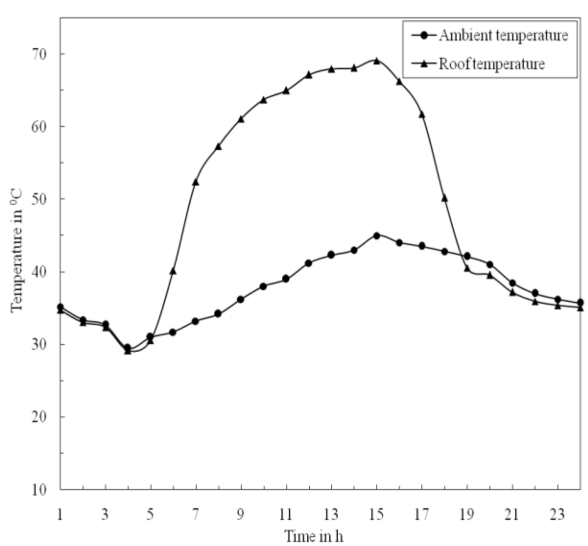
Table 2

Fourier coefficients of solair temperatures coefficient for a summer day of May month of Aligarh

n	Sol–air temperatures for bare surface ($T_{f,sa}$)		Sol–air temperatures for wetted surface ($T_{fw,sa}$)		Sol–air temperatures for painted surface ($T_{fp,sa}$)	
	Amplitude (^{0}C)	Phase (rad)	Amplitude (^{0}C)	Phase (rad)	Amplitude (^{0}C)	Phase (rad)
0	48.86	–	22.7	–	39.16	–
1	20.07	0.27132	4.4344	0.40874	7.51862	0.81082
2	2.6467	0.10978	2.5746	1.42102	1.0158	0.27413
3	4.2953	0.06046	0.83432	0.01989	0.90629	0.37186

4Result and discussion:

Table3 shows the hourly variation of bare, wetted and painted roof surface temperature. The Hourly variations in roof temperatures for the typical summer day by using the different passive cooling are presented in Figs. 3–5. The ambient air temperature is also given in these figures to observe the effective cooling. Bare roof without any treatment gives the maximum roof temperature 69.07^{0}C at ambient temperature of 45^{0}C due to the high absorptivity of metallic surface during day hours. However during the night hours the temperatures of roof fall down to the ambient air (Fig3).



International Journal of Mechanical Engineering
ISSN : 2277-7059 Volume 4 Issue 1 (January 2014)
http://www.ijmejournal.com/ https://sites.google.com/site/journalijme/

Fig3 Hourly variation of the roof temperature for bare roof

Table 3

Result for variation of roofs temperature with ambient temperature

Time in hour	Ambient temperature (^{0}C)	Bare Roof temperature (^{0}C)	Wetted Roof temperature (^{0}C)	Painted Roof temperature (^{0}C)
1	35.2	34.77	20.01	35.13
2	33.4	33.07	19.58	33.39
3	32.7	32.37	19.44	32.73
4	29.5	29.14	18.35	29.55
5	31.0	30.55	18.82	31.05
6	31.7	40.16	20.64	32.95
7	33.2	52.43	23.04	35.88
8	34.2	57.33	23.96	37.4
9	36.2	61.09	24.81	39.62
10	38.0	63.71	25.43	41.51
11	39.0	65.01	25.71	42.52
12	41.2	67.17	26.4	44.68
13	42.3	67.96	26.73	45.69
14	43.0	68.1	26.93	46.28
15	45.0	69.07	27.5	48.1
16	44.1	66.25	26.87	46.87
17	43.5	61.74	25.94	45.76
18	42.8	50.2	23.61	43.76
19	42.1	40.55	21.6	43.59
20	41.0	39.24	21.18	41.68
21	38.5	37.2	20.33	40.6
22	37.0	35.92	19.93	38.14
23	36.2	35.37	19.86	36.69
24	35.7	35.1	19.94	35.55

Wetted roof surface provides the evaporation from the roof due to unsaturated ambient air. This is more effective in arid region due to the higher difference in dry and wet bulb temperatures of the ambient air. It prevents the heat to be absorbed by the roof surface and simultaneously provides the evaporative cooling. Therefore, the wetted roof temperatures are much lower than the ambient air (Fig 4). However, the water requirement for such arrangement is very high and it is a main constrain in the arid region to adopt this technique.

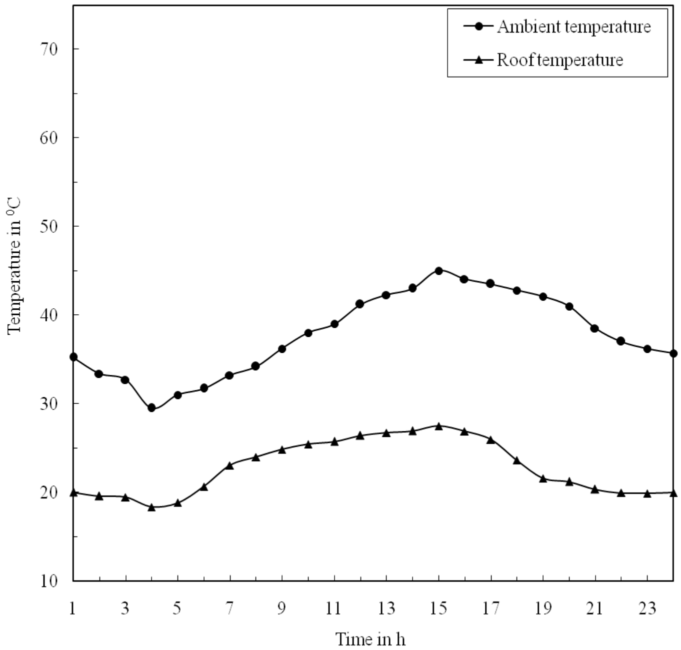


Fig4 Hourly variation of the roof temperature for wetted roof surface

The painted roof surface is also a suitable technique used for cooling in arid region. In this Technique roof is painted with paints having high reflectivity. In the present study White paint of reflectivity 0.9 has been considered. As evident in Fig 5The roof temperature remains within the moderate range from 35^{0}C to 48 ^{0}C which is very slightly than the ambient temperature from 7hrs to 19hrs, means the painted roof surface follow the same pattern as the ambient temperature remaining negligibly higher during the day.

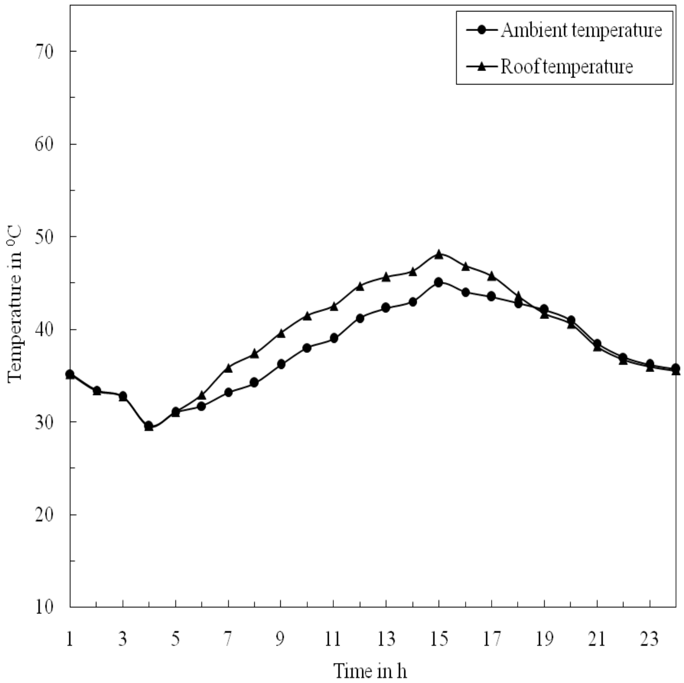


Fig5 Hourly variation of the roof temperature for painted roof surface

5. Conclusion:

Owing to the results discussed in the previous chapter it is concluded that the water sprinkled gunny bags on the roof top for reducing the total space load is most economical technique for the purpose. However care must be taken to prevent the wastage of water by re-circulating the water being drained from the roof top, specially in the arid regions.

6. References:

[1].Nahar NM, Sharma P, Puurohit MM. "Studies on solar passive cooling techniques for arid areas". Energy Conversion and Management 1999; 40:89–95.
[2].Nahar NM, Sharma P,Purohit MM."Performance of different passive techniques for cooling of buildings in arid regions". Building and Environment 2003; 38:109–116.
[3].Szoklay SV. "Thermal comfort and passive design". In: Boer KW, Duffie KA, editors. Advances in solar energy.Plenum Press, New York, 1985. vol. II. p. 257.
[4].Gupta JP, Nahar NM, Chaurasia PBL, Sharma P. "Design consideration for passive cooling of rural houses in arid areas". In: Proc. NSEC 1989, Renewable Energy for Rural Development. Tata McGraw Hill, New Delhi, 1989. p. 249.
[5].Catanoloth S, Cuomo V, Piro G, Ruggi DV. Solar Energy 1975; 17:81.
[6].Jain SP. Proc. National Seminar on "Thermal Comfort in Building by Solar Passive Architecture". The Institute of Engineers (India), Jodhpur Centre, 1994. p. 5.
[7].Harrison AW. Solar Energy 1978; 20:85.
[8].Hay HR, Yellot JJ. ASHRAE Trans. 1969; 5:178.
[9]."A revolutionary new way to insulate, repair, maintain & preserve roof & wall systems, both exterior & interior." Thermal Barrier Coating. Research page on the web./ http://www.interstateproducts.com/white_roof_coating.htm.
[10]."Energy saving roof coating test data".Research page on the web./http://www .interstateproducts.com/roofcoat_test_data.htm.
[11].Jain Dilip."Modeling of solar passive techniques for roof cooling in arid regions". Building and Environment 41 (2006) 277–287.
[12]. Jain D,Tiwari GN."Thermal aspect of open sun drying of various crops".Energy 2003; 28:37–57.
[13].Threlked JL.Thermal environment engineering. New Jersey: Prentice-Hall; 1970.
[14].Khatry AK,Sodha MS,Malik MAS.Periodic variations of ground temperature with depth and time. Solar Energy1978;20:425–7.