COOLING EFFECT OF ROOF TOP LAWNS

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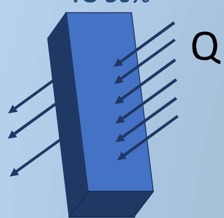
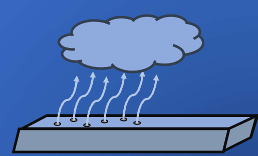
EVAPORATIVE COOLING EFFECT OF ROOF LAWN GARDENS

HEAT FLUX REDUCED TO 50%



COOLING EFFECT DUE TO EVAPORATION



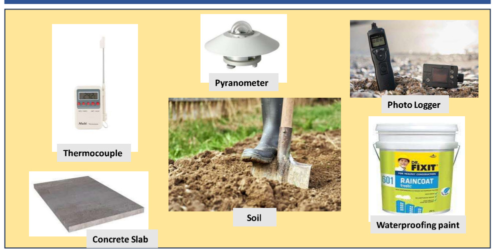
1D UNSTEADY STATE HEAT ANALYSIS

$$\frac{d}{dx}\left(k\frac{dT}{dx}\right)+Q=0$$

Objectives

- ➢ Investigate the evaporative cooling effect of roof lawn gardens planted in non-woven fabric as a mode of passive cooling.
- ➢ Confirm through field measurements during summer that roof lawn gardens reduce the amount of heat entering rooms.
- ➢ Determine the decrease in surface temperature of the roof slab during daytime
- ➢ Estimate the reduction in heat flux into the room as a result of the decrease in surface temperature.
- ➢ Recognize the importance of the evaporative cooling effect from roof lawn gardens in reducing heat flux.
- ➢ Conduct analysis of heat and moisture transport within the roof lawn garden to evaluate its evaporative cooling effect.

Methods and Materials



Experimental Setup: Preparing the rooftop with soil and plants, followed by waterproofing

Data Logging: Utilizing thermal instrumentation to record temperature(air and surface) and solar radiation

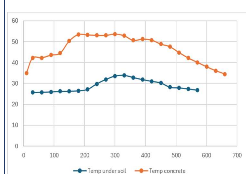
Data analysis: Conducting numerical analysis on the collected data readings.

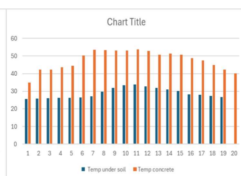
Results

Field measurements demonstrated a 50% reduction in heat flux into a room beneath a roof lawn garden with soil.

The lawn's solar absorptivity was 0.78, indicating its ability to absorb solar radiation.

A simple model of simultaneous heat and moisture transport accurately analyzed hygrothermal behaviors in the lawn layer





Conclusions

The calculated results are in good agreement with the measured values are used in the analysis.

The surface temp of the roof slab decreased from about 60 to 30°C during the day.

The temperature distribution through the thickness of the lawn is influenced not only by the heat flow but also by moisture content

A sensitivity analysis and measurement of parameters are necessary in order to quantitatively evaluate and predict the cooling effect.

Discussion

- ❑ Investigation confirms roof lawn gardens reduce heat entering rooms in summer.
- ❑ Lower surface temperature of roof slab decreases heat flux into rooms.
- ❑ Evaporative cooling effect from gardens crucial in reducing heat buildup.
- ❑ Analysis of heat and moisture transport within gardens evaluates cooling effect.
- ❑ Gardens offer eco-friendly solution for passive cooling in urban areas.

Contact

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References

1. S. Onmura, M. Matsumoto, S. Hokoi, A Study on Evaporative Cooling Effect by Roof Lawn Garden. Part 1. Measurement and Analysis of Evaporative Cooling Effect, in: Summaries of Technical Paper of Annual Meeting, Architectural Institute of Japan, Environmental Engineering, 1992, pp. 767±768 (in Japanese).
2. S Onmura, M Matsumoto, S Hokoi, Study on evaporative cooling effect of roof lawn gardens, Energy and Buildings, Volume 33, Issue 7, 2001,Pages 653-666.
3. Ws-208, Solar concentrator lab, Energy Science dept
4. H. Horita, M. Nakamura, M. Nishiyama, Research of Thermal Environment for Planting on Rooftop, in: Summaries of Technical Paper of Annual Meeting, Architectural Institute of Japan, Environmental Engineering, 1992, pp. 73±74 (in Japanese).
5. K. Mikado, H. Komiya, S. Shiota, H. Sugimoto, Experimental Studyon Effect of Turf Roof. Part 1. An Examination on Thermal Characteristics and Method of Turf Test Model, in: Summariesof Technical Paper of Annual Meeting, Architectural Institute of Japan, Environmental Engineering, 1993, pp. 1525±1526 (in Japanese).

CLL251: HEAT TRANSFER FOR CHEMICAL ENGG

PROJECT REPORT

Study on Evaporative Cooling Effect of roof lawn garden

Abhinav Modi, Nishant Nandan, Sarthak Kumar, Naina Jain

Date- 6 May, 2024

Abstract

In scorching summer heat like you'd find in India, keeping rooms cool is crucial for both comfort and saving on energy bills. This study explored the potential of roof lawns planted in a unique fabric as a natural way to achieve this. Field tests throughout the summer provided strong evidence that these roof gardens significantly reduced the amount of heat entering rooms. The roof's surface temperature dropped from a scorching 50 degrees Celsius to a much more manageable 30 degrees Celsius during the daytime. Based on this, calculations suggest a remarkable 50% reduction in heat flow into the rooms below. These findings point to the evaporative cooling effect from roof lawns as a significant factor in bringing down heat gain. We must investigate how heat transfer occurs within the roof lawn system, considering the rate of evaporation, to fully understand and predict this effect. The results from our calculations closely matched the real-world measurements, further supporting the idea that roof lawns offer significant cooling benefits. However, for even more precise evaluation and prediction, we need to perform sensitivity analyses on the factors influencing heat and moisture movement and refine our model based on additional measurements.

1.Introduction

In recent years, there has been a rise in global warming due to various factors which affects the temperature and the atmosphere and due to urbanization and deforestation there has been a much significant decline in vegetation, to solve both the problems at once rooftop plantation comes to save the day for us. The research of roof top garden has been increased because they are effective not only in promoting the tree planting campaign but also provides the cooling effect of roof lawn by evaporation which is significant change that we will study in this project.

The objective of this study is to investigate the evaporative cooling effect cooling effect of roof lawn garden, First, a reduction in the heat flux into the room will be shown based on field measurements.

2. Field Measurement

2.1 Outline of field measurements

Field measurements were carried out on the roof of 2 stories building in New Delhi (India) in April-May 2024. The lawn garden was set on a roof concrete slab with no beams or walls. Since high-rise buildings were not present around this building, shadows or reflected solar radiation did not influence measurements. The base of the lawn garden was taken to be the roof itself with a waterproofing layer.

Fig.1 shows a schematic diagram of the lawn garden used in this experiment. The lawn garden was composed of loamy soil. Water was supplied at a single time of the day. The size of the lawn garden was 1m x 1m, and the total thickness of the lawn was 10 cm.

The following items were measured every half hour on 2 May 2024:

- Surface temperature of the concrete slab with the sample layer;
- Surface temperature of the concrete slab without the sample layer;
- Outdoor air temperature;
- Solar radiation;

These items were measured simultaneously. The measured data was recorded on a photo logger and converted to data values for later graphical representation. The outdoor air temperature values were extracted from the data uploaded by IMD (India Meteorological Department). Solar radiation was measured by a global pyranometer that gave the sum of direct and diffused sky solar radiation. A thermocouple measured the surface temperature of concrete below the lawn garden.

The lawn temperature and the temperature in the planting layer were not measured since the primary purpose of field measurements at the time was to see whether the evaporation from the roof lawn garden decreased roof temperature appreciably or not. No measurements were carried out in the field experiment concerning the amount of supplied water and water temperature.

2.2 Results of field measurements

Figure in 1st graph Shows the results from field measurements. The rooftop measured in both cases with a lawn garden (case A, hereafter) and that with a sample layer (case B) are shown, along with the outdoor air and wet-bulb temperatures. The wet-bulb temperature was calculated using the measured air temperature and relative humidity. The measured solar radiation is shown in 2nd graph

Under these weather conditions, the surface temperature of the concrete slab in Case-A is much lower than that in Case-B during the day. Cases A and B's daily maximum temperature difference was most significant when the skies were clear (about 20^{o}C). The decrease in the concrete slab surface temperature due to the sample layer effectively reduces the space cooling load and improves the room's thermal environment.

The following compares the heat flux into the room between the two cases by simple transient thermal calculation. Computational conditions are described as follows.

The heat coefficient of air is taken to be 6W/m^2C. The calculation is a one-dimensional unsteady analysis, and the measured temperature of the slab surface is used to determine the boundary condition.

. Different values of heat coefficient are taken. However, the heat flux (Case-A/Case-B) ratio is almost the same (50%).

While the outside weather conditions strongly influence the surface temperature of the concrete slab in Case B, the sample layer also affects the results in Case A. The influential factors are as follows:

- thermal resistance and capacity of the sample;
- solar absorption by the sample;
- convective heat transfer at the sample surface; and
- latent heat transfers due to vapour movement at the sample surface.

The set of parameters used are:

- Conductivity of concrete ($k_{concrete}$)= 0.8W/m C
- Rate of evaporation = 295.42 W
- Absorptivity of solar radiation= 0.77
- Latent Heat of evaporation = 2260 KJ/Kg
- Thickness of roof = 0.3m
- Film coefficient of air = 6W/m^2 C
- Conductivity of lawn sample = 0.116

3. Procedure

The lawn's surface temperature was measured using a thermocouple and a photo logger to record the readings.

Since the lawn layer was regarded as a porous material in this model, convective transfer of heat and vapor was assumed to occur only at the lawn layer's surface. The solar radiation was considered to be absorbed throughout the lawn layer.

The calculation is a one-dimensional, unsteady analysis.

Our experimental setup:

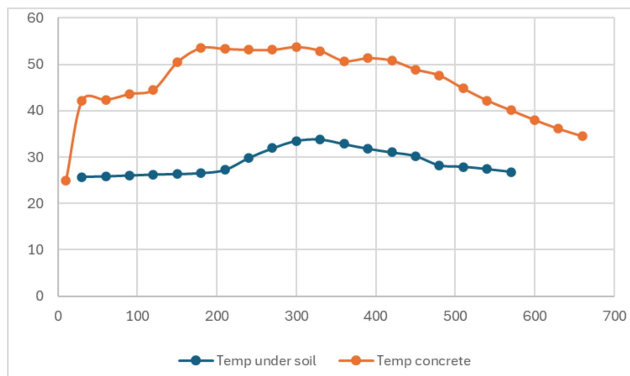
4. Computational Results

Temperature readings:

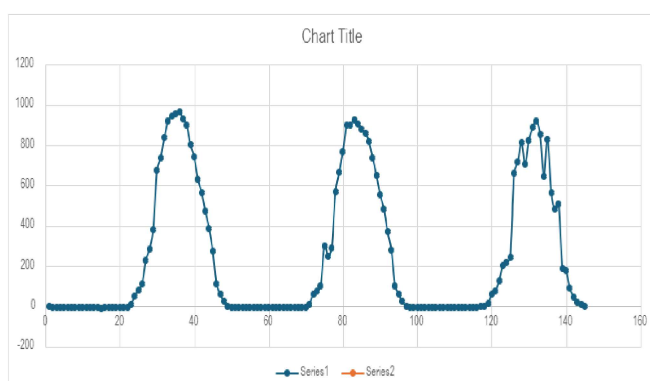
Temp under soil	time (in min)
25.7	30
25.8	60
26	90
26.2	120
26.3	150
26.5	180
27.2	210
29.8	240
31.9	270
33.5	300
33.8	330
32.8	360
31.8	390
31	420
30.2	450
28.2	480
27.9	510
27.4	540
26.8	570

Temp concrete	time(in min)
25	10
42.2	30
42.3	60
43.6	90
44.5	120
50.4	150
53.5	180
53.3	210
53.1	240
53.1	270
53.7	300
52.9	330
50.7	360
51.3	390
50.8	420
48.9	450
47.6	480
44.8	510
42.2	540
40.1	570

Temp vs time plot of the observed data:



Global horizontal irradiance(GHI) vs time plot:



Solar radiation data:

Timestamp	2CV	DNI (W/m2)	GHI (W/m2)	time
00:00.0	1.076202	121.3579	289.03632	09:00
30:00.0	3.382828	381.4642	568.406	09:30
00:00.0	4.065285	458.4214	663.4436	10:00
30:00.0	4.518112	509.4845	769.69184	10:30
00:00.0	5.852463	659.9524	900.37384	11:00
30:00.0	5.722222	645.2658	900.60192	11:30
00:00.0	5.748093	648.1831	925.17936	12:00
30:00.0	5.41275	610.3682	902.37024	12:30
00:00.0	5.459206	615.6068	879.63176	13:00
30:00.0	5.515984	622.0093	859.26752	13:30
00:00.0	5.323006	600.2482	817.77456	14:00
30:00.0	4.849098	546.8081	738.1828	14:30
00:00.0	4.345322	489.9998	649.67016	15:00
30:00.0	3.967171	447.3576	555.68652	15:30
00:00.0	3.61438	407.5752	483.624	16:00
30:00.0	3.093643	348.8544	369.21892	16:30
00:00.0	2.591477	292.2276	280.39978	17:00
30:00.0	0.334946	37.77012	101.61054	17:30

Timestamp	TZ	2CV	DNI (W/m2)	Internal Temp. (degC)
00:00.0	n	1.076202	121.35786	OverRange
30:00.0	n	3.382828	381.46424	OverRange
00:00.0	n	4.065285	458.4214	OverRange
30:00.0	n	4.518112	509.48448	OverRange
00:00.0	n	5.852463	659.9524	OverRange
30:00.0	n	5.722222	645.26576	OverRange
00:00.0	n	5.748093	648.18312	OverRange
30:00.0	n	5.41275	610.36824	OverRange
00:00.0	n	5.459206	615.60676	OverRange
30:00.0	n	5.515984	622.00932	OverRange
00:00.0	n	5.323006	600.24824	OverRange
30:00.0	n	4.849098	546.80812	OverRange
00:00.0	n	4.345322	489.99976	OverRange
30:00.0	n	3.967171	447.3576	OverRange
00:00.0	n	3.61438	407.5752	OverRange
30:00.0	n	3.093643	348.85436	OverRange
00:00.0	n	2.591477	292.22756	OverRange
30:00.0	n	0.334946	37.770116	OverRange

GHI (W/m2)	time	Air Temperature(T∞)	Conc. Temperature(T at y = d) Lawn sample	Conc. Temperature(T at y = d) without Lawn sample	Air Temperature(T∞) ^{0}C
289.03632	9:00	95	25.7	35.7	35
568.406	9:30	95	25.8	40.8	35
663.4436	10:00	97	26	42.3	36.11111111
769.69184	10:30	95	26.2	43.6	35
900.37384	11:00	95	26.3	44.5	35
900.60192	11:30	93	26.5	50.7	33.88888889
925.17936	12:00	93	27.2	53.5	33.88888889
902.37024	12:30	93	29.8	53.3	33.88888889
879.63176	13:00	91	31.9	53.1	32.77777778
859.26752	13:30	90	33.5	53.1	32.22222222
817.77456	14:00	90	33.8	53.4	32.22222222
738.1828	14:30	88	32.8	52.4	31.11111111
649.67016	15:00	86	31.8	50.7	30
555.68652	15:30	86	31	51.3	30
483.624	16:00	84	30.2	50.8	28.88888889
369.21892	16:30	84	28.6	48.9	28.88888889
280.39978	17:00	84	27.9	47.6	28.88888889
101.61054	17:30	82	27.4	44.8	27.77777778

Our reading footage:

Conclusion

Field measurements demonstrated a 50% reduction in heat flux into a room beneath a roof lawn garden with soil.
The lawn's solar absorptivity was 0.78, indicating its ability to absorb solar radiation.
A simple model of simultaneous heat and moisture transport accurately analyzed hygrothermal behaviors in the lawn layer.

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References

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