International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 4 Issue 3 || March 2015 || PP.07-14

A Study on Indoor Temperature and Comfort Temperature

M.Ponni[1] Dr.R.Baskar[2]
[1]*Research Scholar, Department Of Civil & Structural Engineering,*
[2]*Associate Professor, Department Of Civil & Structural Engineering,*
Annamalai University,Chidambaram-608 001, Tamil Nadu, India.

ABSTRACT: *A residential building is a dynamic system in which the internal heat gains occur mainly through roof and walls. The heat transmission to the inside of a building is primarily based on the outdoor temperature. The indoor environment of a building consists of two primary variables. One is indoor temperature (IT) and the other is indoor relative humidity (IRH). The indoor temperature is a combination of radiations received through the roof and walls of the building. If the indoor temperature is too high (summer), or too low (winter) then the building is said to be thermally uncomfortable.In the above two,cases thermal performance of the building is said to be poor. Increasing or decreasing the indoor temperature to a satisfactory level of the occupants leads to comfort temperature. The comfort temperature is the critical state of the indoor temperature. In this study, a new design of roof, based on passive cooling has been constructed, in which hybrid techniques were incorporated to bring down the indoor temperature.The daily mean indoor temperatures obtained were very close to the comfort temperature in summer and is within the comfort band in the other seasons of the year.*

KEY WORDS*: Indoor environment, Indoor temperature, Indoor Relative Humidity, Comfort Temperature, Outdoor Temperature.*

I. INTRODUCTION

The earth revolves around the Sun in an elliptical orbit of very small eccentricity. The earth completes one revolution in one year having the sun at one of the foci. The axis of rotation of the earth is inclined at about 231/2˚ with respect to the plane of revolution. As a consequence, large seasonal variations occur in the amount of solar radiation received at different latitudes of earth. The largest annual variations occur near the two poles and the smallest near the equator. Even the smallest variations bring unbearable thermal effects to the buildings and the occupants. The temperature is too high in summer and low in the winter regarding the living things. The thermal conditions outside the buildings affect the indoor. The indoor temperature needs some limitations for human comfort.The comfort temperature is a result of dealings between the occupants and the indoor environment of the building or the other environment in which they reside. Occupants comfort depends on the mean indoor temperature. This in turn depends on the outdoor temperature. The indoor of a building should not be too warm or too cold. The feasible indoor temperature for satisfactory living is a must for the occupants. The temperature which provides thermal comfort or thermal neutrality to the occupants is known as comfort temperature. Thermal comfort is one of the most essential aspects of user satisfaction and energy consumption in buildings [1].

Human Comfort consists of six factors. The first two factors are personal factors and the remaining four factors are environmental factors.

[1]. Metabolic rate (met): The energy generated from the human body (1 met = 58 W/m^2)
[2]. Clothing insulation (clo): The amount of thermal insulation the person is wearing. 1Clo = $0.155 m^2.K/W$)
[3]. Indoor Air Temperature (Ti): Temperature of the air surrounding the occupant. Or it represents the indoor temperature.
[4]. Outdoor Temperature (To): The weighted average of all the temperatures from surfaces surrounding an occupant.
[5]. Air velocity (Va): Rate of air movement.
[6]. Relative humidity (Rh): Percentage of water vapour present in the air.

Determination of the comfort temperature has two approaches: One is the Fixed Temperature Approach and the other is the Variable Temperature Approach. The Fixed Temperature Approach: The Fixed Temperature Approach or the Heat balance model represents a well-rooted school of thought. For a very long period comfort means only a fixed temperature 23°C or 24°C with a range of 1or 2˚C on either side. Comfort Zone for fixed temperature approach is 23±1°C, ±5% relative humidity and Comfort Range (tolerance) is from 23°C to 25°C for all the time and for all the places irrespective of other conditions.

The heat balance model analyses thermo physiology in detail by assuming controlled steady-state conditions and high accuracy for all analysed variables such as activity level, thermal resistance of clothing, air temperature, mean radiant temperature, relative air velocity, and water vapour pressure in ambient air [2]. Fanger's deterministic heat balance model which formed the basis for these standards, excludes all forms of human adaptation other than in clothing (Nicol, 2004). According to the ASHRAE Standard 55-2004, thermal comfort is a state of mind where a person expresses satisfaction with the thermal environment. The ASHRAE Seven point thermal sensation scale or the Predicted Mean Vote Scale (PMV) and the Predicted Percentage of Dissatisfied (PPD) are given below Fig.1.

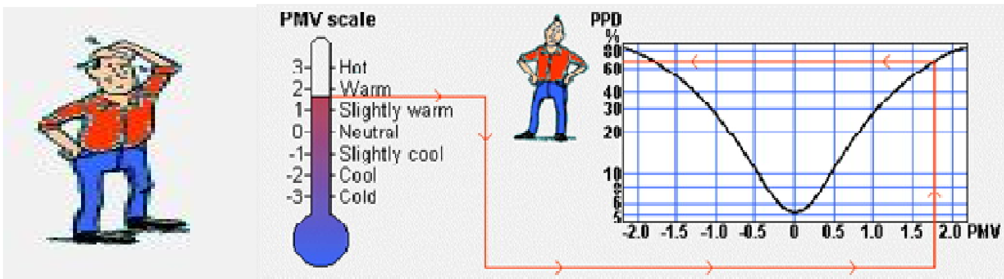

Figure1: ASHRAE: Seven - Point thermal sensation scale (Source: ASHRAE 2003)

The PMV index predicts the mean response of a large group of people according to ASHRAE Thermal Sensation Scale. PMV related to the imbalance between the actual heat flow from the body in a given environment and the heat flow required for best comfort at the specified activity.The Adaptive Comfort Approach or The Variable Temperature Approach: The Adaptive Comfort Approach has been emerged just 40 years ago. Few years ago, there was no thermal Comfort for India. Fixed Temperature Approach serves as a benchmark for the comparative study of variable temperature approach. Human beings adapt in many ways (physiological, psychological, behavioural and use of controls) in their journey to seek thermal delight from discomfort (Heschong, 1979). Due to the adaptation of human beings the comfort temperature is not the same for all places. No universal comfort temperature has been predicted to suit all the occupants of all the regions of the globe. Hence every region must have its own comfort temperature with an intuition according to its climate, regional culture and building type. Recent studies are following the adaptive approach.

The adaptive model investigates the dynamic relationship between occupants and their general environments based on the principle that people tend to react to changes that produced is comfort by seeking methods of restoring their comfort levels [3]. General standards may not be appropriate for all climates, however in a Brazilian study, the minimum air velocity has been proposed for three different operative temperature ranges as follows: 0.4m/s for 24–27˚C, 0.41–0.8 m/s for 27–29 ˚C, and 0.81 m/s for 29–31 ˚C [4]. Very little thermal comfort studies have been carried out so far in India. For all climate and building types, the National Building Code of India specifies the use of too narrow ranges of two bands of temperatures for summer and winter. For summer it is (23–26˚C) and for winter it is (21–23˚C), (BEE, 2005). In India there are six climatic conditions. The six climatic zones are given with their monthly mean temperature, relative humidity and the respective cities. Coastal regions of India have the warm and humid climate which is obvious from the fig.2. This warm and humid climate has a temperature around 30˚C and relative humidity 55%.

Climate	Mean Monthly Temp(˚C)	Relative Humidity (%)	Representative City
Hot and Dry	30	<55	Jodhpur
Warm and Humid	30	55	Mumbai
Moderate	25 - 30	<75	Bangalore
Cold and Cloudy	<25	55	Simla
Cold and Sunny	<25	<55	Leh
Composite	This applies when six months or more do not fall within any of the above categories		New Delhi

Table I: Six climatic conditions and thermal data

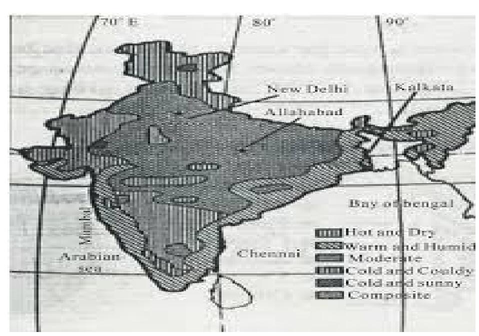

Figure 2: India and climatic zones

A study conducted in Himachalpradesh predicts a minimum comfort temperature 18.46˚C in Manali during January and a maximum comfort temperature 29.05˚C in Unaduring July [5]. A field study on the basis of adaptive approach was conducted in the Naturally Ventilated apartments of Hyderabad, during summer and monsoon, in 2008. The analysis resumed a comfort temperature of 29.23°C and the comfort band of 26 - 32.5°C, and the relative humidity range of 17% - 78% [6]. The occupants adapted through clothing and metabolism to remain comfortable. Clothing insulation varied from 0.19 – 0.84 clo in this study, while metabolism varied from 0.7 – 2.0 Met (sleeping – standing working). Understandably, subjects chose lighter clothing (0.15- 0.3 clo) and took post- meal naps during the hot mid-day in summer. Some men at home were found in lungi (a 2 m x 1.4 m long cloth draped around the waist), and left the upper body bare, when at home, during the hot period. Some female subjects were observed using lighter clothing during heavy kitchen work. Older women (age more than 40yrs) for example, were usually dressed in saris (clo = 0.55 to 0.66), a culturally more acceptable costume, even when other lighter clothing options were available (long gown = 0.29 clo).

A study conducted in Surakarta, Indonesia with the low income group reported that the mean neutral temperature was found as 32.5˚C, which is higher than some other cities in Asia. Thermal comfort assessments in that research found that the comfort band width is from 30 to 35˚C .However, more people prefer to have a smaller range between 33 - 34˚C[7].This is highest comfort temperature found so far. According to [8], the neutral temperature or the comfort temperature based on the adaptive approach (adaptive model) is the temperature at which a person should be neither too hot nor too cold. The comfort zone is 2˚C below and above the neutral temperature. On the other hand, [9] has set the comfort zone for 90% acceptability to be 2.5˚C above and below the neutral temperature [10]. Indoor comfort hinges on the adaptive use of various electrical controls like hand held fans, ceiling fans, air coolers and air conditioners etc.,[11]. The use of controls also depends on the indoor and outdoor temperatures. The effect of air movement on comfort is equivalent to a drop in indoor temperature of up to 4°C. Ceiling fan is the most commonly used low- energy environmental control [12] and is significant to human thermal comfort.[13] presented a very interesting fact on the use of fans, that the buildings with less open windows, people resort to use electro mechanical controls like fans higher. The above finding supports the finding of Hwang et al, (2008). The author, [14] further found that even in mixed mode buildings with adaptive opportunities provides the same level of thermal satisfaction.

The indoor comfort temperature can be related to climate, region and seasons. According to different surveys held under different climatic conditions, for free running buildings, the comfort temperature can be obtained from the mean outdoor temperature.
The comfort temperature equation formulated by Humphrey's [3] is as follows:

$$Tc = 0.534To+11.9 \quad (1)$$

For naturally ventilated and air-conditioned buildings [15] has proposed an equation for comfort temperature. The relation is given by the following equation:

$$Tc = 0.31To + 17.6 \quad (2)$$

Nicol et al has conducted several surveys under different climatic conditions. In a first survey in Pakistan [16], he established a relation between comfort temperature and outdoor temperature is given by

$$Tc = 0.38To + 17.0 \quad (3)$$

In the second survey in Islamabad, Pakistan, Nicol has found a second regression equation as follows:

$$Tc = 0.36To + 18.5 \quad (4)$$

The SCATS survey [17] conducted in five European Countries has increased the accuracy and applicability of the model. The daily mean outdoor temperature was related to the indoor comfort temperature. The assumptions made were

[1]. Thermal resistance of the clothing is 0.5 (clo)
[2]. Metabolic rate is 1.4 (met)
[3]. Air velocity is 0.15 (m/s)
[4]. Relative humidity is 50%

The comfort temperature regression equation proposed was

$$Tc = 0.33T0+18.8 \quad (5)$$

According to the comfort studies, the equations proposed have a common feature. The comfort temperature equations are based upon the outdoor temperature. Since the other factors are assumed to be constant, the variation of outdoor temperature is taken into account. The comfort temperature varies from month to month according to the seasons. The selection of building for the determination of the comfort temperature varies from one author to other. The studies have been carried out in different climates.

The adaptive methods followed in Chidambaram, Tamil Nadu are mostly similar with the adaptive methods of Hyderabad study. Hence the comfort temperature and the comfort range of Hyderabad study are considered to be applicable to this place.

II. RESEARCH DESCRIPTION

The size of the module is 3mx 3m x 3m. The galvanized sheets used in the modules have the same thickness of 0.21 mm. The walls have a thickness of 230 mm made up of brick and cement mortar. Two angles are used as purlins. It is a low sloped roof and is maintained to be 2˚. Walls of the modules are white washed and the flooring is done with cement mortar. The indoor temperature and the relative humidity of the module were recorded Hygro thermometer. Single channel data logger has been utilised for this recording. The outdoor temperature is obtained from the local meteorological records. This study considers an experimental module constructed on passive approach involving hybrid techniques. The aim of the study is find out, the closeness of the indoor temperature provided by the experimental module with the comfort temperature. And also the comfort temperatures calculated through different studies for the outdoor temperatures of this place are to be compared with the indoor temperatures.

Double decker (DOD) : The roof of the module is newly designed. The design can be carried out in four steps. In the first step, first roof was made using galvanised sheets. In the second step wooden reapers of size 3000 mm X 50 mm X 25 mm were arranged over the roof. The spacing between the reapers is 200 mm. In the third step packed mineral wool roll was spread. Thickness of the mineral wool is 50 mm. In the fourth step galvanized sheets were set over it as second roof. The two roofs are separated by 100 mm to 122 mm. Since light roofing system have two light roofs enclosing the wooden reaper and mineral wool, it was named as Double Decker. Since the sheets are trapezoidal, air gap of 11 mm above and below the mineral wool pack and wooden reapers is formed. The air vents created are the passage for the air and takes away the heat produced between the galvanized sheet and the mineral wool bed. Likewise the air vents created between the lower roof sheet, the wooden reaper and the mineral wool bed is also drains away the heat produced by convection. The mineral wool, wooden reapers and the air enclosed in the gaps are serving as insulators. This assembly possesses three insulators wooden reapers, mineral wool and air gap. Mineral wool has a low thermal conductivity among the building materials used (K= 0.04 W/m K).

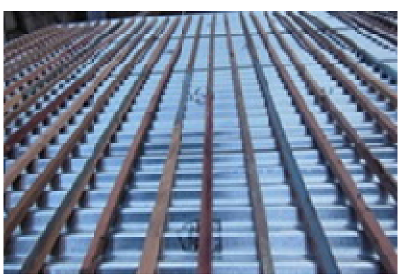

Figure.3 First two steps of roof construction

Figure.4 Third and Fourth steps of roof

Figure.5 Completed stage

III. RESULTS AND DISCUSSION

For various mean out door temperatures, the comfort temperatures have been calculated through different thermal comfort studies. The mean outdoor temperature of Chidambaram lies within the range of 24˚C to 34˚C.

Using different equations, comfort temperature has been calculated for different mean outdoor temperatures and is given in table II. This table provides comfort temperatures for a wide range of mean out door temperatures from 5˚C to 35˚C. Since the mean out door temperature of Chidambaram city is known, the comfort temperature can be read from the Table II. The study-4 gives the comfort temperature of 27.14˚C in winter for the mean outdoor temperature of 24˚C. And the comfort temperature is 30.74 in the summer for the mean outdoor temperature of 35. The comfort temperature of Chidambaram according to Nicol's second survey lies within the range of 27.14˚C to 30.74˚C. The comfort temperature values obtained from study-4 are higher comparing with other studies. But according to Hyderabad study the upper and lower limits of comfort temperatures are from 26to 32.5˚C. No equation was proposed by the author to find out the comfort temperature. If the outdoormean temperature is known, any region or any place can find out its comfort temperature, from this Table II.

TableII: Different mean outdoor temperatures and comfort temperatures

Mean Outdoor Temperature	***Comfort Temperature calculated by Different Studies***				
	Humphrey	*Auliciem*	*Survey1 Nicol*	*Survey 2 Nicol*	*Scats Survey*
5	14.57	19.15	18.9	20.3	20.45
6	15.1	19.46	19.28	20.66	20.78
7	15.64	19.77	19.66	21.02	21.11
8	16.17	20.08	20.04	21.38	21.44
9	16.71	20.39	20.42	21.74	21.77
10	17.24	20.7	20.8	22.1	22.1
11	17.77	21.01	21.18	22.46	22.43
12	18.31	21.32	21.56	22.82	22.76
13	18.84	21.63	21.94	23.18	23.09
14	19.38	21.94	22.32	23.54	23.42
15	19.91	22.25	22.7	23.9	23.75
16	20.44	22.56	23.08	24.26	24.08
17	20.98	22.87	23.46	24.62	24.41
18	21.51	23.18	23.84	24.98	24.74
19	22.05	23.49	24.22	25.34	25.07
20	22.58	23.8	24.6	25.7	25.4
21	23.11	24.11	24.98	26.06	25.73
22	23.65	24.42	25.36	26.42	26.06
23	24.18	24.73	25.74	26.78	26.39
24	24.72	25.04	26.12	27.14	26.72
25	25.25	25.35	26.5	27.5	27.05
26	25.78	25.66	26.88	27.86	27.38
27	26.32	25.97	27.26	28.22	27.71
28	26.85	26.28	27.64	28.58	28.04
29	27.39	26.59	28.02	28.94	28.37
30	27.92	26.9	28.4	29.3	28.7
31	28.45	27.21	28.78	29.66	29.03
32	28.99	27.52	29.16	30.02	29.36
33	29.52	27.83	29.54	30.38	29.69
34	30.06	28.14	29.92	30.74	30.02
35	30.59	28.45	30.3	31.1	30.35

Fig.6 shows the relationship between the mean outdoor temperatures and comfort temperatures through different studies. For low outdoor temperatures the comfort temperature is high. But for the high outdoor temperatures the comfort temperature is low. For the mean outdoor temperatures from 5˚C to 28˚C, the calculated comfort temperature values through different studies are higher. For the mean out door temperature values from 29˚C to 35˚C, the comfort temperature values are less. For a low mean outdoor the comfort temperature is high, but for the high mean outdoor the comfort temperature is less in all the cases.

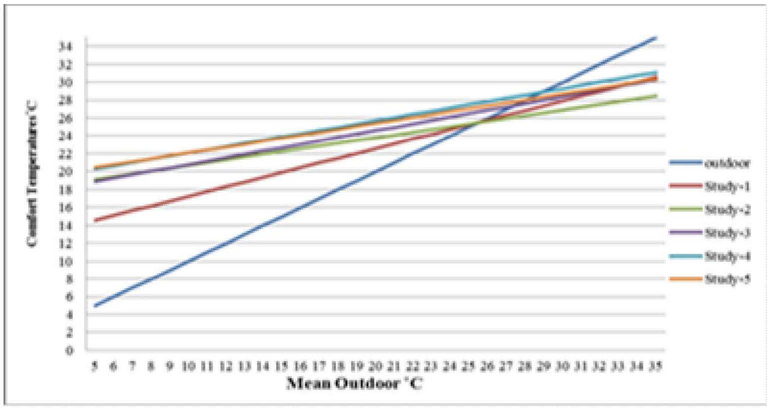

Figure 6: Mean Outdoor Temperature and Comfort Temperature

Table III: shows the comfort temperatures based on the monthly mean outdoor temperatures for the monitoring period through different studies. The comfort temperatures are less than the monthly mean outdoor temperatures except in the winter season. The monthly mean indoor temperature of the experimental module has been compared with the monthly mean outdoor temperature for the monitoring period. From November to February during winter the indoor temperatures provided by the module is higher than the outdoor temperatures. The indoor temperatures for these months are closer to the comfort values calculated through different studies and it is within the limits given by Hyderabad study.

Comfort Temperature calculated by different studies							
Months	*Monthly Mean outdoor To*	*Humphrey*	*Auliciem*	Survey 1 Nicol	Survey 2 Nicol	*Scats Survey*	*Monthly Mean DOD indoor*
Sep-13	29.88	27.86	26.86	28.35	29.26	28.66	29.03
Oct-13	29.66	27.74	26.79	28.27	29.18	28.59	28.82
Nov-13	26.65	26.13	25.86	27.13	28.09	27.59	27.02
Dec-13	25.29	25.41	25.44	26.61	27.6	27.15	26.38
Jan-14	25.65	25.6	25.55	26.75	27.73	27.26	26.31
Feb-14	26.95	26.29	25.95	27.24	28.2	27.69	27.31
Mar-14	29.34	27.57	26.7	28.15	29.06	28.48	29.44
Apr-14	32.7	29.36	27.74	29.43	30.27	29.59	32.03
May-14	31.47	28.7	27.36	28.96	29.83	29.19	31.04
Jun-14	32.67	29.35	27.73	29.41	30.26	29.58	32.17
Jul-14	31.84	28.9	27.47	29.1	29.96	29.31	31.43
Aug-14	30.97	28.44	27.2	28.77	29.65	29.02	30.25

Table III: shows the relationship between the mean outdoor temperatures and the comfort temperatures calculated and the measured indoor temperature of the DOD module. The monthly mean outdoor for the monitoring period and the comfort temperatures calculated through different studies are shown in fig.7. The mean indoor temperature is slightly higher when the comfort temperature is low. The mean indoor is slightly lower when the comfort temperature is high. The results resemble the results in the figure.4. The mean indoor is within the comfort band limits of the study [8].Fig.7 shows the Comfort, monthly mean outdoor temperatures and DOD indoor temperatures for the monitoring period. Comfort band upper and lower limits are drawn based on the Hyderabad Study.

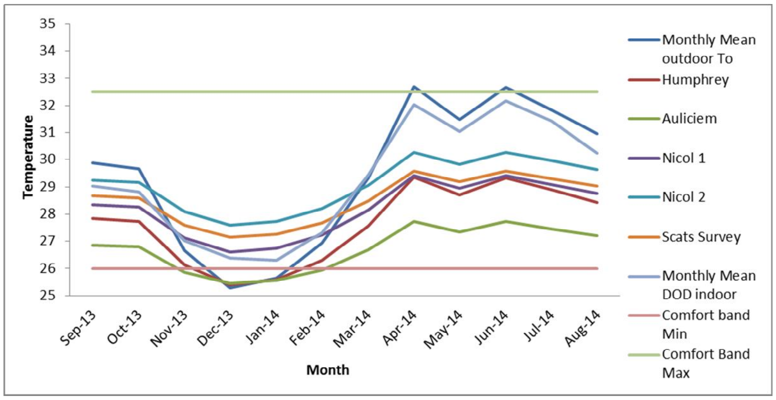

Figure.7 The indoor comfort temperature and the monitoring period

Starting from the month of September to February the indoor temperature is within the comfort level. From March to August the indoor temperature reaches a maximum of 32.5˚C. The performance of this DOD module parallels the comfort limits of Hyderabad Study [8]. The outdoor mean temperature is low for the months from November to March 2014, than the mean indoor temperature of the DOD module. During June 2014, the outdoor temperatures were so high. The comfort temperatures for this month have been calculated using different studies and are compared with the indoor temperatures provided by the module. The month of June had a high temperature continuously than the other months.

Table IV: shows the relationship between the mean outdoor and comfort temperatures calculated through different studies and daily indoor mean temperatures.

Comfort Temperature through Different Studies						
June mean outdoor Temperature	*DOD June mean Indoor Temperature*	*Humphrey*	*Auliciem*	*Survey 1 Nicol*	*Survey 2 Nicol*	*Scats survey*
33.5	32.63	29.79	27.99	29.73	30.56	29.86
33.5	32.9	29.79	27.99	29.73	30.56	29.86
30.5	30.27	28.19	27.06	28.59	29.48	28.87
32	31.17	28.99	27.52	29.16	30.02	29.36
33	31.43	29.52	27.83	29.54	30.38	29.69
33.5	32.3	29.79	27.99	29.73	30.56	29.86
32.6	32.03	29.31	27.71	29.39	30.24	29.56
32.5	32.5	29.26	27.68	29.35	30.2	29.53
31.5	31.43	28.72	27.37	28.97	29.84	29.2
32.5	31.8	29.26	27.68	29.35	30.2	29.53
33	32.03	29.52	27.83	29.54	30.38	29.69
33	32.67	29.52	27.83	29.54	30.38	29.69
31	30.7	28.45	27.21	28.78	29.66	29.03
33	32.77	29.52	27.83	29.54	30.38	29.69
33	32.9	29.52	27.83	29.54	30.38	29.69
32.5	31.73	29.26	27.68	29.35	30.2	29.53
32	31.73	28.99	27.52	29.16	30.02	29.36
32	31.77	28.99	27.52	29.16	30.02	29.36
32.5	31.73	29.26	27.68	29.35	30.2	29.53
33	32.57	29.52	27.83	29.54	30.38	29.69
32.5	32.27	29.26	27.68	29.35	30.2	29.53
33	32.8	29.52	27.83	29.54	30.38	29.69
32.5	32.37	29.26	27.68	29.35	30.2	29.53
33.5	33.13	29.79	27.99	29.73	30.56	29.86
33.5	32.87	29.79	27.99	29.73	30.56	29.86
33	32.8	29.52	27.83	29.54	30.38	29.69
34	33	30.06	28.14	29.92	30.74	30.02
33.5	32.93	29.79	27.99	29.73	30.56	29.86
33	32.63	29.52	27.83	29.54	30.38	29.69
31.5	31.17	28.72	27.37	28.97	29.84	29.2

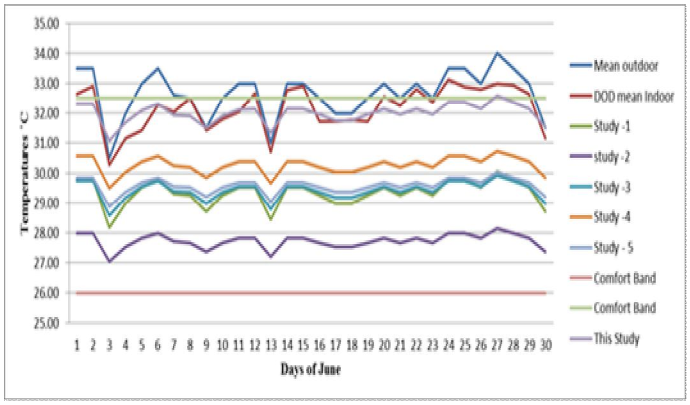

Figure.8 Shows the relationship between Comfort, indoor and outdoor Temperatures of June -2014

The indoor temperature is within the comfort band for 20 days or 66% of the days in June. It is seen that the indoor temperature of the module for the rest of the days is above the comfort temperature but closer to the comfort band. The performance of the module shows an agreeable result to the light roof users.

IV. CONCLUSIONS

This study clearly demonstrates the significant impact of a simple and effective hybrid passive cooling system in reducing thermal loads of roofs. The experimental results demonstrate that the newly designed roof reduces the indoor temperature. Hybrid passive cooling technique used in this study is highly effective. It provides economic feasibility and indoor temperature achievability. The indoor temperatures of DOD fall within and closer to the comfort band limits of the Hyderabad study.

REFERENCES

[1] Nicol, F., Humphreys, M., Roaf, S., *Adaptive Thermal Comfort: Principles and Practice* (Routledge, London,2012).

[2] Fanger P., *Thermal Comfort: Analysis and applications in environmental Engineering*(McGraw-Hill Book Company, United States, 1970).

[3] Humphrey's, M.A. *Outdoor Temperatures and Comfort Indoors, in Building research Establishment*, Building Research Station Department of Environment, pp. 75,(1978).

[4] Cândido.C, deDear,R, Lamberts, R.,2011, Combined thermal acceptability and air movement assessments in a hot humid climate*Building and Environment* 46 (2), 379– 385.

[5] Thermal Comfort Temperature Standards for Cold Regions S. S. Chandeland R. K. Aggarwal

[6] MadhaviIndraganti Proceedings of Conference: *Adapting to Change Thermal Adaption and impediments: Findings from a field study in Hyderabad*, India(2010).

[7] Stanley R. Kurvers et al Comfort Temperatures for the Low-Income Group in a Hot- Humid Climate Proceedings of 7th Windsor Conference: The changing context of comfort in an unpredictable world Cumberland Lodge, *Windsor, UK,12-15* April 2012

[8] Hyde R. *Climate Responsive Design*, First Edition, E & FN Spon(UnitedKingdom, pp.76-81.2000).

[9] Szokolay S, Introduction to Architectural Science: *The Basis of Sustainable Design*, First Edition, Architectural Press, Oxford, (UK, 2004, pp. 20-21, 64-70, 225-227).

[10] Auliciems A, *International Journal of Biometeorology*, 1981, 25: pp. 101-122.

[11] Nicol, J. F., Raja, I. A., Allaudin, A., &Jamy, G. N. Climatic variations in Comfortable temperatures: the Pakistan projects*Energy and Buildings*, 30(1999) pp.261- 279.(1999).

[12] Wong, N. H., et al.Thermal comfort evaluation of naturally ventilated public housing in Singapore,*Building and Environment*, 37 (2002) 1267 – 1277.(2002).

[13] Raja, I., Nicol, J. F., McCartney, K. J., & Humphreys, M. Thermal comfort: Use of controls in naturally ventilated buildings *Energy and Buildings*, 33 (2001) 235- 244.(2001).

[14] Hwang, R.-L., Cheng, M.-J., Linc, T.-P., &Hod, M. C. Thermal perceptions, general adaptation methods and occupant's idea about the trade-off between thermal comfort and energy saving in hot–humid regions, *Building and Environment*(2008).

[15] Auliciems, A. and S. Szokolay Thermal Comfort PLEA Note 3. PLEA International / University of Queensland(1997).

[16] Nicol, F., Jamy, G.N., Sykes, O., Humphrey, M. Roaf, S. and Hancock, M. A Survey of Thermal Comfort in Pakistan: Toward New Indoor Temperature Standards Oxford Brookes University School of Architecture.(1994).

[17] McCartney, K.J., Nicol, J.F. Developing an adaptive control algorithm for Europe *Energy and Buildings* 34(6), 623–635.2002.