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ENHANCEMENT IN THE PERFORMANCE OF THERMAL RADIANT COOLING SYSTEM

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ABSTRACT

In terms of energy consumption, radiant cooling system has an advantage over conventional system. A significant amount of systems is consumed by fans, which are used to transport cool air through the ducts. Part of this electricity used to move the air also heats the conditioned air and, therefore, is part of the internal thermal cooling load. If the tasks of ventilation and thermal conditioning of buildings are separated, the amount of air transported through buildings can be significantly reduced. In this case the cooling is provided by radiation using water as the transport medium and the ventilation by outside air systems without the need for recirculation and cooling of air. Although the supply air necessary for ventilation purposes is still distributed through ducts, the electrical energy for fans and pumps can be reduced to approximately 25% of that of conventional air-conditioning system.

This experiment studies the application of radiant cooling using natural air for ventilation under hot and humid climate of Rajasthan. To avoid condensation of moisture on the cooling panel, the temperature of water supplied to the panel was limited to dew point temperature. The results generally confirm the good potential for application of radiant cooling.

KEYWORDS: Radiant cooling, Eco friendly, cost effective design, Global warming, Human Comfort, Water Cooler.

INTRODUCTION

The use of radiant heating and cooling is not new, the roman used under floor radiant heating and thermal mass heat storage in their 2000 years ago. In turkey, stream water was run through channels on walls and floor to cool places in the warm summers. In the 1930s, architect Frank Lloyd Wright piped hot water through the floor of many of his buildings.

Radiant cooling is a gentle temperature conditioning system, exchange thermal energy to the space through convection and radiation. Convection air conditioning unit are only designed to control air temperature whereas in radiant cooling, Radiant energy travel through space without cooling the air itself but rather object.

Radiant cooling system has been employed in the system comprises panels installed on the ceiling of a room, or in some cases hung from a high ceiling. Cooling water is supplied to the panels at temperature above dew-point temperature of air in the room to avoid condensation of moisture in the air on the panels. Heat is transferred between the space and the cooling panels through a temperature differential. The cooling panels absorb heat through a combination of radiation and convection. Radiative heat transfer occurs through a net emission of electromagnetic waves from the warm occupants and their surroundings to the cool ceiling [1] On the other hand, the room airs convicts heat to the cool panels and create convection current within the space.

Radiant cooling panels are normally used with displacement ventilation where ventilation air is introduced into a room at low level and flows by natural means to replace existing air. In a typical radiantly cooled office building, two to three air exchanges per hour is required. The ventilation air drawn from outdoor should be dehumidified in order to reduce latent load since the cooling panels remove sensible load only. Radiant cooling systems are usually hydronic, cooling using circulating water running in pipes in thermal contact with the surface. Typically the circulating water only needs to be 2-4°C below the desired indoor air temperature.[2] Once having been absorbed by the actively cooled surface, heat is removed by water flowing through a hydronic circuit, replacing the warmed water with cooler water.

Table.1: Thermal conductivity of various materials

Materials	Thermal Conductivity (W/mK)
Aluminium sheet	204
Copper tube	385
Plywood	0.17
Glass Wool	0.04

The experiment showed that with a cooling ceiling the vertical temperature asymmetry is less than 1.1°C, acceptable value which not create a discomfort in the occupancy zone [3]. Another important aspect of the test was the effect of the chilled ceiling on the thermal comfort. The temperature of the ceiling was changed in order to see the effect on the thermal comfort.

The concept of energy efficient building assets in a sub-tropical climate, building assets must adopt a number of innovative strategies to take advantage of subtropical climate [4]. The importance of energy efficiency improvement in building asset is elaborated with the justification of the utilisation of the low energy cooling technologies.

The thermal sensation under non-uniform conditions, the operative temperature only is not sufficient. Highly non-uniform environments, can achieve a comparable or even more comfortable assessment compared to uniform environments [5].

This study demonstrates that the ceiling radiant cooling panel system creates uniform temperature distribution inside the conditioned space [6]. The ceiling radiant cooling panel system improves indoor air quality (low noise and minimum supply air are used when compared with conventional cooling system).

The parametric studies included relative humidity, air velocity; age and gender on thermal comfort of radiant cooling system in tropical climate of Thailand have been proposed [7]. Thermal comfort was evaluated using thermal sensation, humid sensation and air movement sensation.

The temperature of the floor surface increased with the pipe pitch increasing in the floor radiant cooling systems, regardless of the floor structure [8]. The range of the floor surface temperature is relatively smaller. The CRCP/DOAS system with 100% fresh air can save more than 26.1% of input power over a VAV system with 100% fresh air [9].

The advantages of hydronic radiant floor heating include the efficient use of space and that cleaning is not required [10]. Also, the system does not produce noise, cause drafts or use ducts. The system has uniform temperature distribution and is a low-temperature heating system.

The panel cooling can meet its capacity duty, and only use about 50% of the ceiling in most cases [11]. The study are useful for building owners, engineers and users trying to understand the operation, benefits and drawbacks of implementing chilled ceilings in buildings [12]

EXPERIMENTAL WORK

Fabrication of Radiant Cooling System

Test chamber of Radiant Cooling System

The Material selected for the test chamber fabrication is plywood because thermal conductivity of plywood not high, so less heat loss to atmosphere, easily available in market at reasonable cost and folding structure.

The test chamber was design to simulate actual office conditions. The available alternatives regarding the location of the test chamber viz. outdoor with solar exposure and inside a room were discussed exhaustively .The discussion concluded that the test chamber should be placed inside the room so as to facilitate convenient fabrication. The placement is based on the underlying assumption that the reading obtain from the radiant panel would not be affected significantly even if the test chamber is devoid of solar exposure. The dimension of the test chamber is 4 ft*6 ft *8ft.The height was suggested to be optimal for recording the thermal stratification developed in the room due to the chilled ceiling. Glass wool and radiant barrier has been placed above the ceiling to reduce the heat gain from roof.
The test chamber should be placed inside the lab so as to facilitate convenient fabrication. Test chamber walls are made by ply wood. Two walls has dimension 4 ft * 8 ft and two wall has dimension of 6 ft * 8 ft, one wall has a door has dimension of 2 ft *6 ft. In the door there is a window of 1 ft * 2 ft, is provided to observe the internal conditions.

Fig.1: Radiant cooling Chamber

Ceiling Radiant Cooling System

Thermal conductivity of Copper is very high so that a very good heat transfer can take place between the fluids in the tubes and the cooper tube. The thermal conductivity of copper remains almost same with change in temperature.

Although thermal conductivity of aluminium is lower than copper but due higher cost of copper we use aluminium as the base of the copper tube in ceiling Radiant Cooling System and Glass Wool is spread over copper tubes to reduced heat gain from the environment.

A 4*4 sq. ft radiant cooling panel constructed from cooper tube bonded to aluminium sheet has been installed on the ceiling. The chilled water is circulated through copper tubes and the heat transfer from the working fluid is setup by convection and radiation.

The tubes are mounted on the metal sheet by riveting. However the contact area available for heat transfer from the fluid to the sheet is limited due to the line contact. Thus a thin aluminium sheet (<0.5 mm) is used to wrap the copper tubes and extended at the end in the shape of a fin to provide efficient heat transfer.

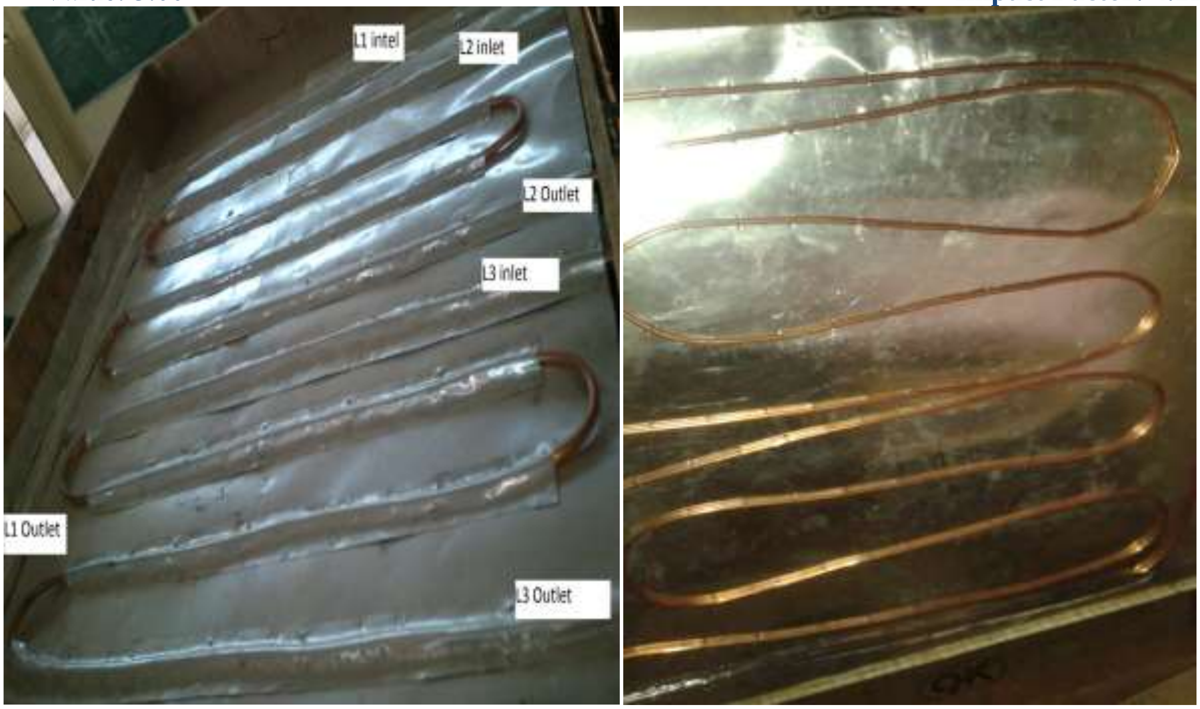

Fig.2: Ceiling Radiant Cooling Panel

Air-conditioning system

Aluminium sheet duct is used because of low weight, easy to handle and low cost of manufacturing.

This test chamber is equipped with a Radiator unit that uses chilled water supplied from water cooler. The air is re-circulating in chamber. Ventilation air is drawn into the test chamber by a fan of 300 mm sweep, 230 AC, 50 Hz, through a duct into an inlet airport. Fresh ventilation air flows from the port. A separate exhaust port of the same size is also provided.

Fig.3: Air Conditioning Duct

Cooling water distribution panel :- The Distributer panel pipes was made of G.I. Pipe. The G.I. pipe was selected of following reasons

- The thermal conductivity of G.I. pipe is not high, so less heat loss to atmosphere and the thickness of G.I. pipe is enough. So that it can take pressure.
- PVC pipes are used to flow the water from the distributer to the Ceiling Radiant Cooling system due to its lower thermal conductivity and Puff is rapped over PVC pipes to reduce the heat transfer to the environment.

Cooling water that flows to the cooling panels and Radiator is supplied from the water cooler. A pump is used to supply the water to the ceiling panel and fan coil. There is a distributer is used to distributed the water and the valves are used to controlled the flow of water in the pipes. There is a returning water pipe which returns the use water to the tank of the water cooler.

Fig.4: Cooling Water Distribution Panel

MEASUREMENT OF TEMPERATURE OF AIR

Air Temperature transducer

It is used to measure the temperature of air with minimum thermal radiation interference from nearby hot and cold objects. To achieve this open ended highly polished aluminium foil cylinder is used in it for enclosing the sensor.

Fig. 5: Air Temperature Transducer

MEASUREMENT OF INSIDE ROOM TEMPERATURE

Resistance temperature detectors (R.T.D) :- The RTD is one of the most accurate temperature sensors. Typical elements used for RTDs are Nickel (Ni), Copper (Cu) and Platinum (Pt). By far the most common are the 100-ohm or 1000-ohm Platinum RTDs, sometimes referred to as PRTs.

In the study RTD sensors were placed at the positions, where temperatures were to be measured, in order to ensure that they are working satisfactorily and have not been damaged in the process of installation, resistance between red wire and two white wires (one by one) was checked with the help of precise digital multi meter. When both the pairs show equal resistance, it indicates that the sensor is working properly and can further be connected to compatible digital temperature display device.

Fig. 6: Three Wire RTD (Resistance Temperature Detectors) Pt-100 Sensors

MEASUREMENT OF RELATIVE HUMIDITY

Thermo hygrometer :- Thermo-hygrometers are instruments used for measuring relative humidity and temperature simultaneously. In our experimentation, Fluke-971 thermo hygrometer was used to measure the relative humidity of air inside the test room and at the outlet of EATHE pipe. The Fluke 971 meter is built for field use with an impact resistant housing, rugged holster, convenient belt clip and bright backlit display.

A large LCD simultaneously displays relative humidity and temperature readings, along with calculating dew point and wet bulb temperatures. Figure 7 shows picture of Fluke-971 Thermo Hygrometer.

Fig.7: Fluke-971 Thermo-Hygrometer

DIGITAL TEMPERATURE INDICATER

Temperature measurements with RTDs first electronically measure the RTD resistance and then convert to temperature using the RTD's resistance versus temperature characteristics. Multiplan makes, MDI 38, 3 wire RTD digital temperature display device has been used to display the temperature measured by various RTD sensors. These temperature display devices are very compact and highly accurate. All these indicators were properly calibrated to give accurate measurement of temperature. Figure 8 shows the picture of one of the temperature display devices used.

Fig.8: Digital Temperature Indicator

EXPERIMENTAL RESULTS

Case-I :- When Copper Tube Fixed on Aluminium Sheet outside the Room of Ceiling

(a) Variation of mass flow rate in individual loops

Individual loops were operated in the outlet water temperature of the three loops were recorded to verify the performance and the heat load capacity of the individual loop in shown in figure shows a greater temperature rise of 3.385°C because of the continuous looping which resulted in decreased with respect to as compared to 2.83°C in loop1 and loop3. The decreasing trend in the temperature difference across the loop inlet and outlet temperature is due to turbulence created by increasing the flow rate. For the room n heat load under consideration, laminar flow inside the tubes provides better heat transfer capacity to CRCP as compared to turbulence flow.

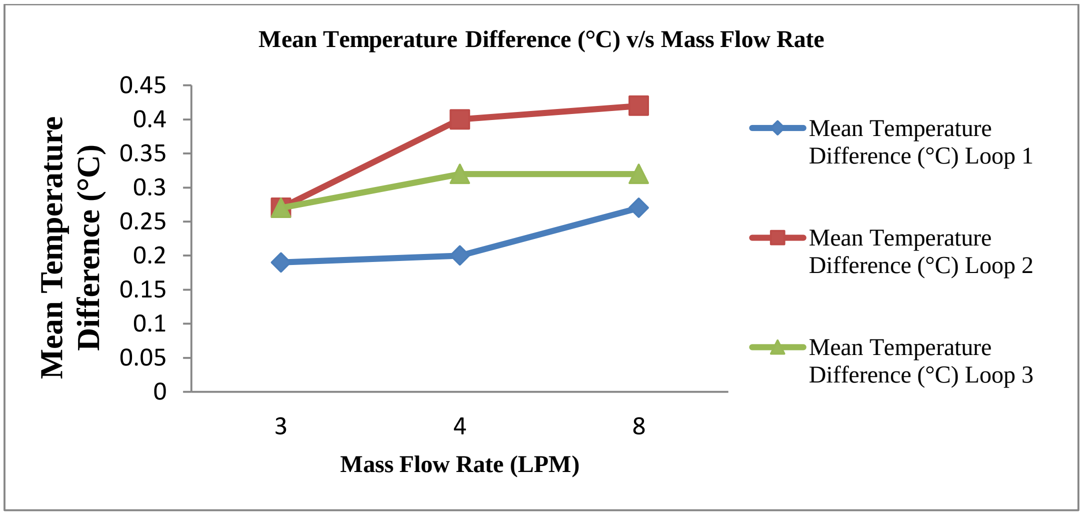

Fig.9: Mean temperature difference and Mass flow rate

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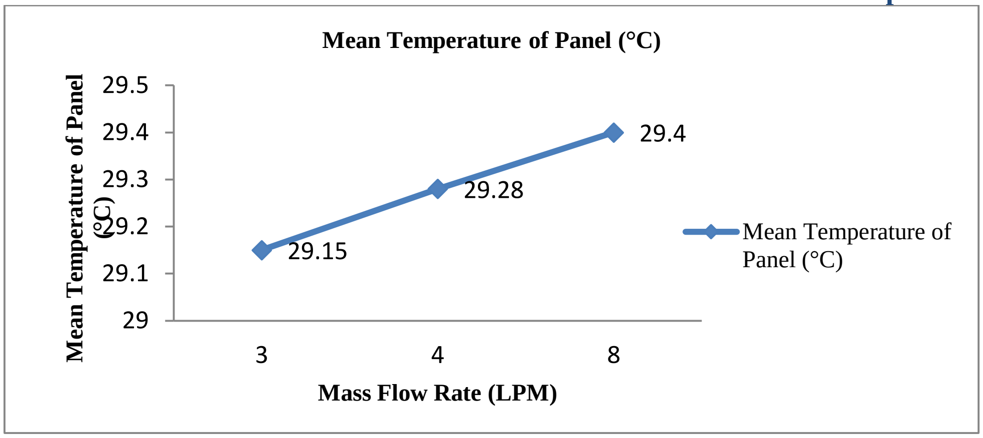

Fig.10: Mean temperature of panel and Mass flow rate

(b) Only Radiant Operation

It was observed that the mean panel temperature continuously decreased with time. The time required for the system to achieve steady state condition be can be approximately 1hr as concluded from the graph above. The condensation issue is not considered in this set of experiments. The mean panel temperature should be maintained 1 to 2 degree above the dew point temperature.

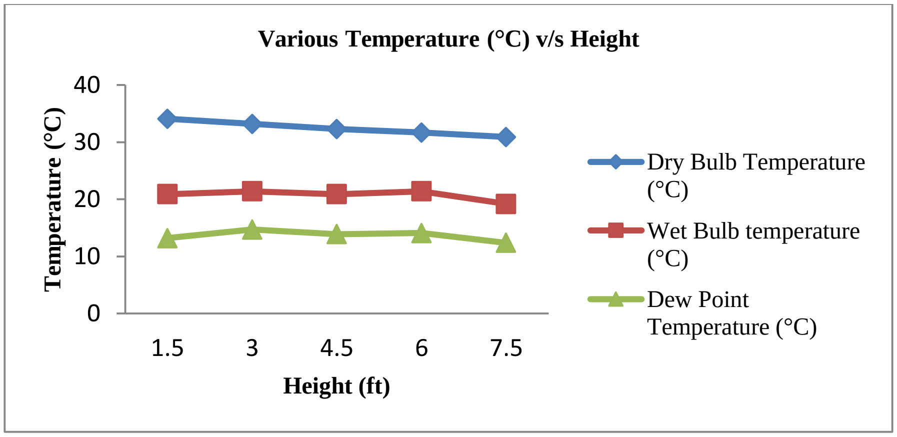

Fig.11: Various Temperature and Height

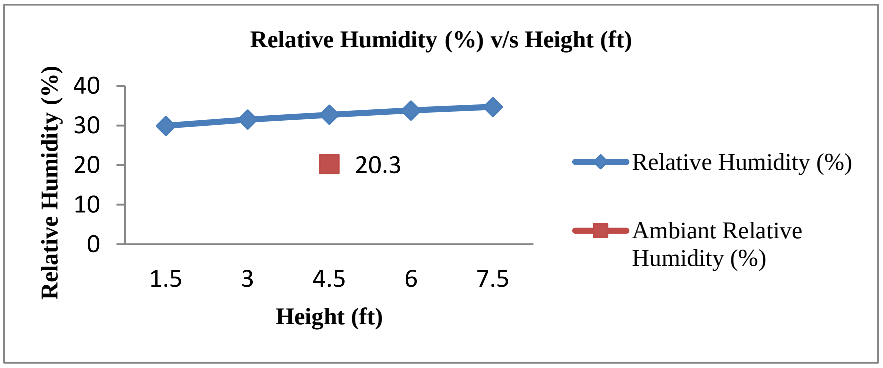

Fig.12: Relative Humidity and Height

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(c) Radiant and Convection Operation

An important conclusion that can be derived from the above experiment result is that the heat carried by the water while only radiant is operational is given by ṁ C p Δ t which is equal to 525W. While the heat carried by the water when convection is setup along with the radiant panel is 735W. Thus the heat carrying capacity of the panel increases by setting up convective in the room.

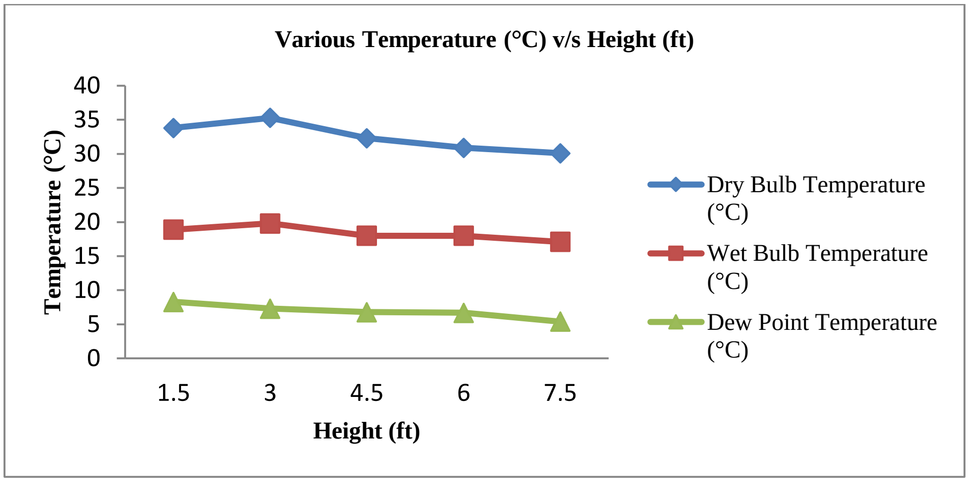

Fig.13: Various Temperature and Height

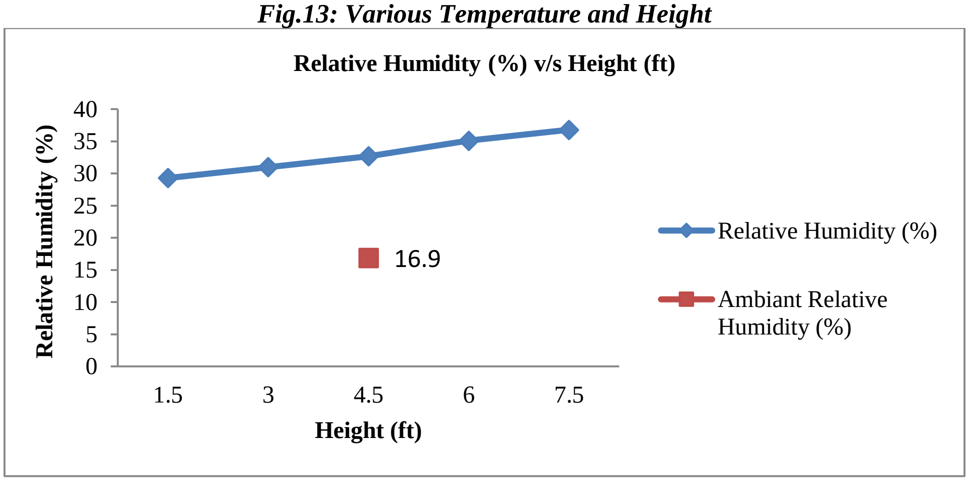

Fig.14: Relative Humidity and Height

Case-II When Copper Tube Fixed on Aluminium Sheet inside the Room of Ceiling

(a) Only Radiant Operation

It was observed that the mean panel temperature continuously more decreased with time with respect to Case-I. The time required for the system to achieve steady state condition be can be approximately 1hr as concluded from the graph above. The condensation issue is not considered in this set of experiments. The mean panel temperature should be maintained 1 to 2 degree above the dew point temperature.

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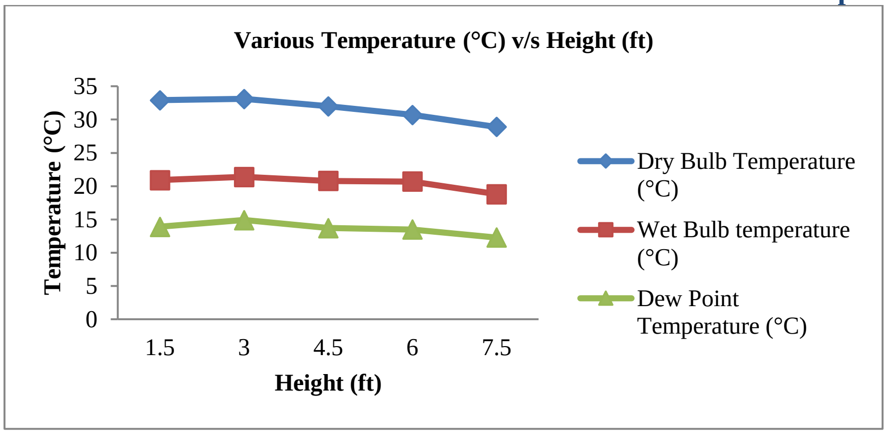

Fig.15: Various Temperature and Height

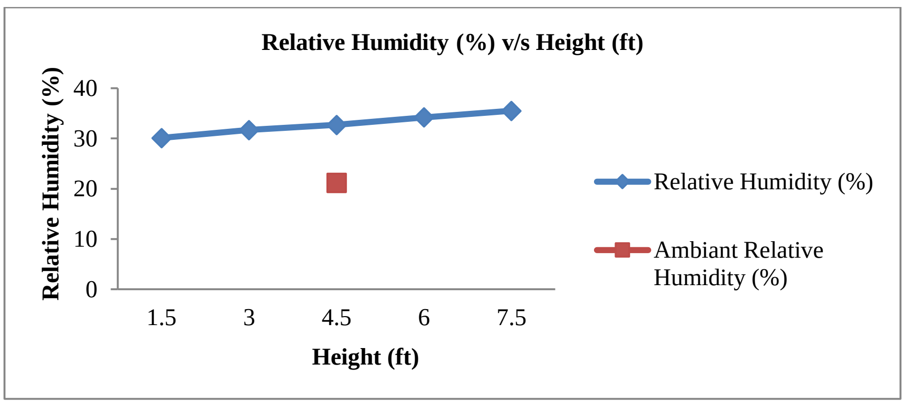

Fig.16: Relative Humidity and Height

(c) Radiant and Convection Operation

An important conclusion that can be derived from the above experiment result is that the heat carried by the water while only radiant is operational is given by ṁ C p Δ t which is equal to 685W. While the heat carried by the water when convection is setup along with the radiant panel is 895W. Thus the heat carrying capacity of the panel increases by setting up convective in the room.

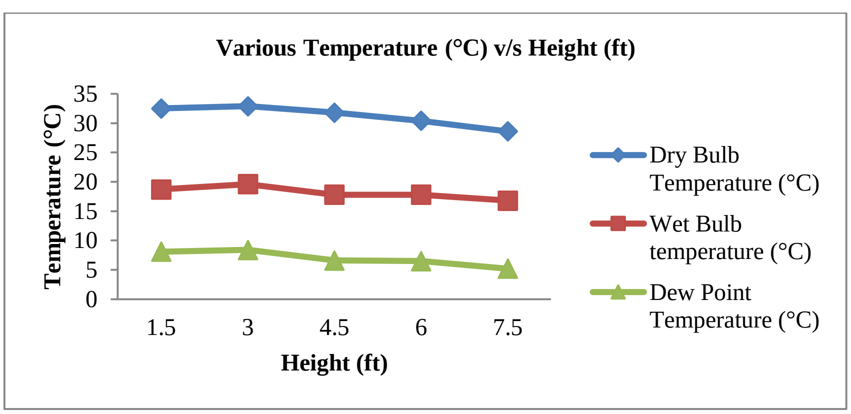

Fig.17: Various Temperature and Height

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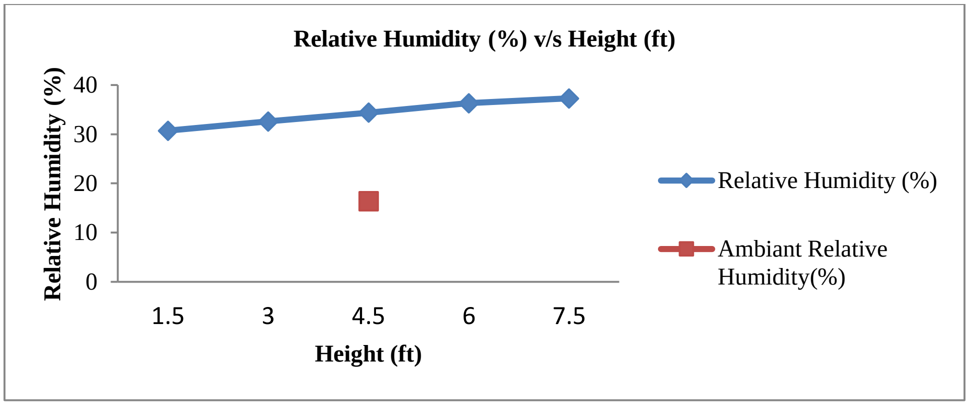

Fig.18: Relative Humidity and Height

CONCLUSION

It can be concluded that the system like Radiant cooling panel spreading over a large portion of the ground can be used as an effective way of cooling .By using Radiant cooling system operational costs are reduced for the mechanical chilling system since cooled ceilings operate at relatively high temperatures (average surface temperature of 29°C). Chillers can operate at higher temperatures resulting in an increase in efficiency and reduction in energy costs. Radiant panels can be used as both heating and cooling panels reducing the amount of equipment and piping required compared to conventional heating and cooling system. Cooled ceilings are silent and virtually draft free since air flow volumes are reduced compared to conventional systems (typical radiantly cooled office building: 2 to 3 air exchanges per hour compared to 6 to 10 with conventional systems). Radiant cooling panels can be retrofitted into the false ceilings of older buildings as the plenum space requirement is minimal relative to fan coil units or VAV systems. Smaller plenums result in savings in building height (1' per floor!) compared to air conditioning systems. This technique allows a 10% reduction of the energy consumption. This cooling technique is suitable for office buildings with low thermal loads. We conclude that their power is limited and the building’s cooling loads must be low.

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