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Economic Assessment of Radiant Cooling Technique in Air Conditioning Building

Purusothaman M, Vedagiri sri harsha, Yuvaraj R, Yadla sai pavan, Yarramsetti

Abstract- Energy supervision in buildings is essential which would manage the energy utilize as well as the cost concerned while maintaining comfort conditions and necessities in indoor environments. In recent years, radiant cooling has acquired a lot of popularity as it can be attributed to the fact that it offers potential to reduce cooling and heating energy consumption by lowering peak loads when coupled with building thermal mass. This can be further enhanced by the application of low energy ventilation systems. Displacement ventilation is one of the techniques to maintain adequate level of air purity and thermal comfort in indoor. The sustainable aspect of these radiant cooling systems to expand the control in Energy and Environmental system design recommendation for low carbon emission in the environment.

Keywords: Economic assessment, Air conditioning, Building, Radiant cooling.

I. INTRODUCTION

There are a lot of good reasons that designers should think the radiant cooling systems in newly constructed buildings. Commercial buildings mainly cooled by radiant cooling systems give high comfort than the buildings cooled by traditional Heat Ventilation and Air Conditioning systems. The lifetime energy savings over the Variable Air Volume systems are around 25% or even more, the initial costs for radiant cooling systems is not compatible with traditional VAV systems [2].

By radiant cooling systems, Heat transfer occurs between their bodies to surfaces i.e. ceilings, walls, or floors-whose temperatures are lower than outside [9]. Space conditioning energy is typically transferred from boilers to concrete slabs by using water as a source. This produces remarkable savings, since water has around 3,500 times the energy carry capability than air.

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*Corresponding author:
Purusothaman M*, Assistant Professor, School of Mechanical Engineering,Sathyabama Institute of Science and Technology, Chennai-119, India. purusothmani@gmail.com
Vedagiri sri harsha, Students, School of Mechanical Engineering,Sathyabama Institute of Science and Technology, Chennai-119, India.
Yuvaraj R, Students, School of Mechanical Engineering,Sathyabama Institute of Science and Technology, Chennai-119, India.
Yadla sai pavan, Students, School of Mechanical Engineering,Sathyabama Institute of Science and Technology, Chennai-119, India.
Yarramsetti Nagendra, Students, School of Mechanical Engineering,Sathyabama Institute of Science and Technology, Chennai-119, India.

With a radiant space cooling system, the volume of air and the components moved are probably five times smaller. Radiant cooling system has more compensation over VAV systems superior indoor air quality because ventilation air is not re-circulated. There are no wet surface cooling coils, thereby dipping the probability of bacterial growth, enhanced user comfort is possible with convective space conditioning. Better efficiency, smaller sizes of chillers and boilers, Lower maintenance costs

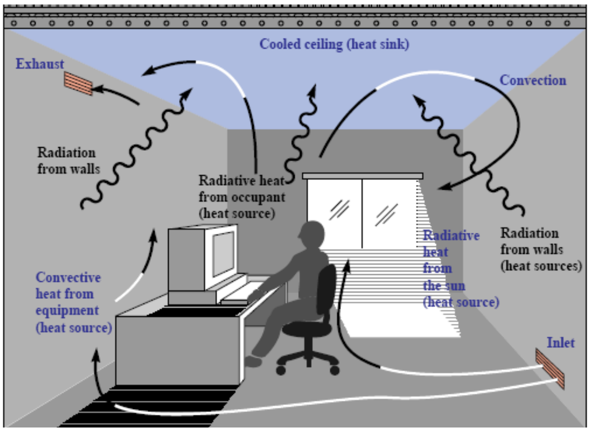

Fig.1 Air Flow & Heat Exchange in Room with Cooled Ceiling

1.1 PRINCIPLE AND ECONOMICS

A radiant cooling system decreases indoor temperatures by dismissing sensible heat. Heat flows from the objects in the space to cooled surface so long as their temperatures are higher than the cooled surface. The effect on atmosphere temperature is negligible during the radiant exchange process, but by the process of heat convection, the air temperature decreases when it is in contact with the cooled surface.

While comparing VAV systems with radiant cooling systems, they save 30% on energy for cooling and 27% on require. Energy saved ranges from 17% in cold, moist areas to 42% in warmer, dry areas. The primary reason for lower savings in humid areas is that significant dehumidification must be employed by both systems. Hence, the amount of energy savings to total energy is lower. Also there is 40 to 55% savings in space requirements.

1.2 TYPES OF RADIANT COOLING SYSTEMS

There are two variant radiant cooling systems. The first system type delivers cooling based structure of building, mainly slabs, they are also called as thermally activated systems. The other type delivers cooling through ceiling panels. Concrete slabs costs lower than panel systems and offers thermal mass, where as panel systems have quick control and flexibility over temperature.

1.2.1 Radiant Concrete Core Cooling

In concrete core cooling, the chilled water pipes are directly embedded into the slabs. Chilled water runs through the pipes cool the slab and radiant cooling can be transferred to space from the ceiling [3]. The radiant heating systems will be the better option for circulation of cooled water. Both the ceiling and floor may be used for cooling. Delivering cooling from the ceiling is more effective than cooling from floor [1]. Therefore cooling from ceiling is best way to get maximum effectiveness.

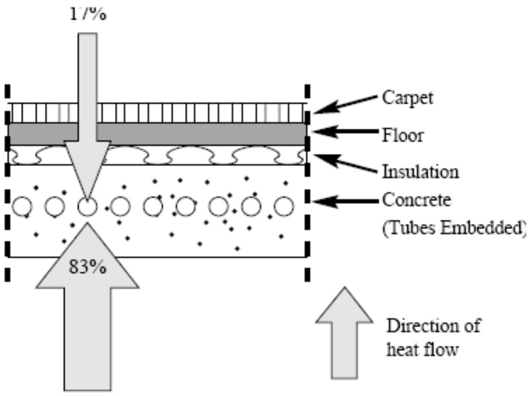

Fig.2 Radiant Concrete Core Cooling

There are lot of design hurdles involved in this type of design i.e. pipe spacing and pipe depth which needs to be carefully designed as per the load and comfort requirements. The structural requirements also need to be carefully. The pipes used for radiant cooling layout are usually made up of high density polyethylene and have extremely high strength and high resistant pressure. The pipes to be arranged in grids (equal spacing) and laid before concrete is done and then become a part of slab after the concrete has been poured. There is no joint inside the concrete slab and pipes are pressure tested at the time of concreting to ensure that there is no leakage.

1.2.2 Radiant Ceiling Panels / Chilled Beams

Radiant ceiling panels are not only fixed to ceilings, but also can be fixed to wall. They offer a low thermal mass as compared to concrete core slabs. However they have high cooling output and faster response time as compared to chilled concrete core slabs [5]. They are perfectly suited for buildings with varying cooling loads and can be easily integrated with ventilation supply from the ceiling [4].

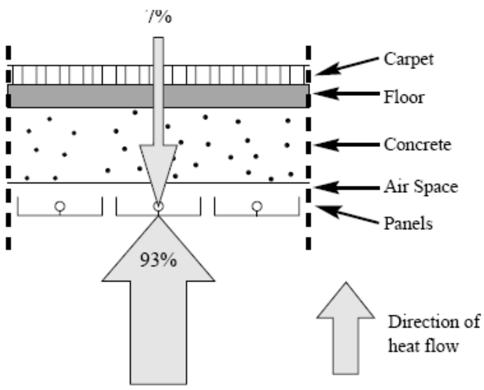

Fig.3 Radiant Ceiling Panels / Chilled Beams

In typical buildings, the way of preventing condensation on radiant panels is straightforward. The condense water from AHU can be used for improve the system performance was reported [8]. A separate system maintains the dew point in the space below the temperature of the radiant panels. In most instances, the common source of top humidity load is the humidity limited in ventilation make-up air. The passenger cabin comforts have been analyzed with PCM roof [6] and experimental investigation have been carried out with PCM roof [7].

II. EXPERIMENTAL, MATERIALS AND METHODS

Space conditioning is done only when there is difference in temperature. It is compulsory to keep up temperature of external surface tubing which carries cooled water above dew point temperature for avoiding condensation.This constraints that air should be well sealed in the buildings at humid areas to undergo dehumidification. It means that cross sectional area of cooling surfaces have to be wide enough to dissipate adequate amount of cooling.For hot and humid conditions and particularly in Indian buildings where cooling load is very high it is necessary to first reduce cooling load by using efficient glazing, shading, reduction in internal lighting, insulation etc., before commissioning of radiant cooling system. For concrete core applications, a small supplemental air based system may be used in conjunction with radiant cooling if loads are still high and cannot be met entirely through chilled slabs.

2.1 AVOID FLOOR CONDENSATION

Proper system design and layout and proper control sequences are crucial in avoiding the possibility of floor condensation. With proper design, condensation should never occur, even in the most humid climates. Condensation avoidance strategies must consider the actual usage and microclimate of the project, in addition to generic peak humidity design conditions.

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2.2 DISPLACEMENT VENTILATION SYSTEM

Cooled and dehumidified air from the Air Controlling Unit will be distributed to conditioned spaces by means of ducting raised vertically and horizontally to floors. Maximum flow velocity in ducts for air conditioning shall be 7.5 m / sec (1500 fpm). Maximum flow velocity in ducts for ventilation toilet exhaust & Kitchen exhaust shall be 7.5 m / sec – 12.5 m / Sec (1500 – 2500 FPM). Maximum friction in the duct shall be 0.65 Pa / M run (0.08 inch WG/100 ft run).

2.3 HEAT LOAD SUMMARY

From the above design parameters and the layouts, the Total air-conditioning load for the proposed building works out to 45 TR. The detailed calculation is given Table 1**.**

Table 1 Heat load summary

HEAT LOAD SUMMARY						
S. N	Items	Area	Cooling Coil [cfm]	Total Load [TR]	Fresh Air [cfm]	Total Load [TR]
1	Basement Floor	1653	1755	7.1	838	10
2	Ground Floor	1598	1905	6.6	638	9
3	First Floor	1152	808	5.5	388	7
4	Second Floor	1501	1703	5.46	463	8
5	Third Floor	1584	2058	6.25	475	9
6	3F Server Room	31	0	1.27	0	1.3
	Total	**7520**	**8229**	**32.18**	**2800**	**45**

2.4 SELECTION OF EQUIPMENTS

Selection of equipment's for the radiant cooling system should have enough care, following are the major equipment's may be used in the system as,

- Water Cooled Water Chilling Units [CHILLERS]
- Cooling Towers
- Water Circulation Pumps
- Air Handling Units
- Network of Piping and Fittings
- Lowside Works

2.5 FLOOR MOUNTED AHU

The AHU shall be of modular type with penta post frame and sandwich panels. The panels and the post shall be manufactured from maximum gauge galvanized steel. Panels and frame shall be secured using internally fixed bolts, so that welding is avoided and the finishing is maintained .The construction shall permit removal of panels for maximum allowance to fans, coils and filters. The casing shall have double skin construction of 25mm or 50mm thick manufactured out of minimum 24G GI with plain powder coated / plasticized sheet as the external skin and perforated sheet for sound absorption or plain sheet as the inside skin.

Total unit is fixed on galvanized metal steel frame for easy handling. The unit shall have a sloped GI / drain pan with a bottom connection to eliminate stagnation of condensate water. All the panels shall be flush mounted. Provide rubber caps for screws protruding within the units. Sealing shall be by means of a non-hygroscopic gasket dense between the frame and the panels. Access panels with hinged doors will be provided to retain and overhaul the fan and filters. The fan section shall have DIDW centrifugal curved blower may be of forward / backward mounted on vibration separation mountings with its bearings fixed on the scroll. The fan must be entire with belt drive package. The impeller and shaft of the fan must be both statically cum dynamically balanced. The drive package shall also be balanced correctly.

The fan and motor assemblage must be fixed on a universal framework completely isolated from the unit by rubber-in-shear or spring vibration mountings. Fan discharge must isolate from casing by canvas. Stipulation shall be made on the air-handling unit for entrance of electrical cables and earth termination.

The motor should be of TEFC spiral cage type having class F insulation and IP 55 safety. The motor shall be of energy competent type with elevated and smooth efficiency curve for 50 to 100% load. Wherever particular present in twin motor with frame work, so that in case of the failure of one motor the other can be put into operation. The motor is appropriate for operation using a frequency drive.

- Insulated Butterfly valves, balancing valves, condensate drain piping, up to floor Air Handling Unit, shall be described in section “Piping”.
- Thermometers in the thermometer wells and pressure gauges (with cocks) within gauge ports in chiller water supply and return lines shall be provided.
- AHU shall be connected to Fire alarm panel and shall automatically switch-off in case of fire. The contractor should provide PF Contractor.
- Two-way Modulating valve with a thermostat.
- By-pass line so that the coil will not be affected during Phosphate Cleaning.
- Filters
- Each unit is attached with a factory filter consists of minimum 50 mm thick washable HDPE panel.

III. RESULT AND DISCUSSION

Total HVAC energy practice and peak demand in cooling may be reduced up to 20% by implement Radiant Cooling System in the explained manner above. The displacement air can be maintain hotter than an all-air system [10], since the radiant cooling to cool people, not the air and the cost of pumping the water is much less than moving the required air with fans.

3.1 CALCULATION OF SAVINGS IN OPERATING COST

Most of the variable air volume systems, ventilation air is supplied less than the requirement to a given space due to unevenness in the system. The only air eliminated and a constant or easily convenient volume of fresh air coming in with much less fan power, ducting, and noise is achieved. Operating the systems economically is the intention of the whole process, using Radiant cooling system the expected saving of 17.1 kW provide the saving on running cost would be Rs. 2,87,280/- by optimizing the power consumption in a year could be 41040 kW-hr bearing in mind the operating diversity of 80% running the plant for 10 hours a day for 300 days per year at a unit rate of Rs. 7 / kW.

Table 2 Comparison on Energy Consumption

S.N	Items	Conventional System [A]	Proposed System [B]
A	Calculated Capacity	45 TR	45 TR
1	Water Cooled Chillers	38.4	28.8
2	Chilled Water Pumps	5	7.5

3	Cooling Towers	10	10
4	Condenser Water Pumps	5	5
5	Air Handling Units	15	5
6	HRW Units	2	2
	Total	**75.4**	**58.3**
	Difference [A - B]	**17.1**	

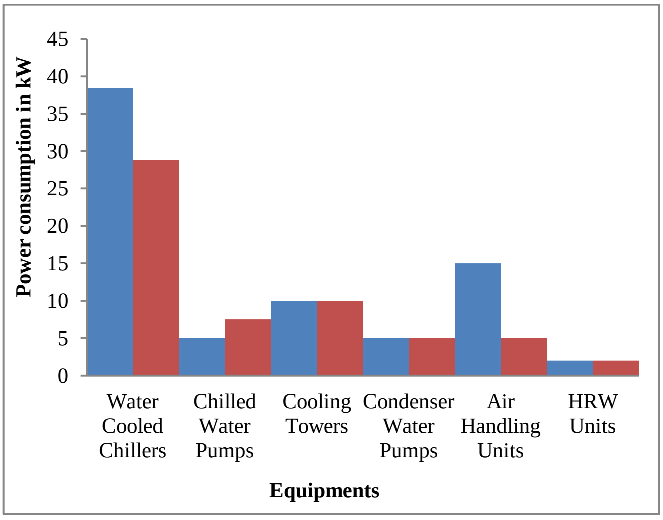

Fig.4 Comparison on Energy Consumption

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3.2 SAVINGS IN INVESTMENT COST

In a lot of cases, the first cost of installation can really be minor when all design impacts are taken into consideration. The condition for fans, ducting, and plenums is much lower with radiant systems. In addition to sometimes lower equipment costs, this saves much space in the building as well, since it reduces the between-floor space requirement which could be results with increasing additional floor.

Table 3 Comparison on Investment Cost

S. N	Items	Conventional System [A]	Proposed System [B]
A	Calculated Capacity	45 TR	45 TR
1	Water Cooled Chillers	14,00,000.00	10,50,000.00
2	Water Circulating Pumps	4,50,000.00	6,00,000.00
3	Cooling Towers	1,50,000.00	1,00,000.00
4	Radiant Cooling Systems	-	3,00,000.00
5	Air Handling Units	7,50,000.00	3,50,000.00
6	HRW Units	3,00,000.00	3,00,000.00
	Total	**30,50,000.00**	**27,00,000.00**
	Difference [A-B]		**3,50,000.00**

IV. CONCLUSION

The shock of global energy utilization has geared up for the progress of proficient and sustainable energy technology wherein thermally assisted building system has a major role to par the gap between the energy supply and demand. Radiant cooling system is the latest low energy technique available but it should be borne in mind that it is not a solution for every building's cooling / heating needs particularly in Indian conditions. Project evaluation is very much necessary before choosing this technique. Health care facilities should be major candidates because radiant space conditioning works well with single-pass ventilation. Traditional HVAC systems that circulate air tend to circulate bacteria but in radiant cooling there is no return air thus there is no chance to circulate bacteria in conditioned space. As low energy air conditioning strategies gain momentum in India, radiant cooling is becoming more common in commercial buildings. But all these hurdles can be overcome with right design process and commitment from the building design team.

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AUTHOR'S PROFILE

M. Purusothaman was born at Madurai on 10.04.1984 and author has done his Master of Engineering in Refrigeration and Air condition with **Distinction and GOLD Medal** from CEG, Chennai and B.E in Mechanical from RVSCET. Author's major field of interest is Greenhouse solar Dryer, Refrigeration and Air Conditioning, Computational Fluid Dynamics, and IC Engines. He has 10 years of Teaching and 1 year of Industry experiences and currently working as an AP in Sathyabama Institute of Science and Technology, Chennai. He has published **16 Scopus indexed journals** in various international and national journals. Mr.M.Purusothaman becomes members in various Professional bodies like ISHRAE, SAE, IAENG, and HKSME.

Vedagiri Sri Harsha was born at Andra Pradesh on 29.06.1999 and pursuing B.E (Mechanical) from Sathyabama Institute of Science and Technology. Author's major area of interest in the following subjects Thermal Engineering, Thermodynamics and IC Engines.

Yuvaraj R was born at Andra Pradesh on 28.04.1998 and pursuing B.E (Mechanical) from Sathyabama Institute of Science and Technology. Author's major area of interest in the following subjects Thermal Engineering, Thermodynamics and IC.

Yadla Sai Pavan was born at Andra Pradesh on 01.04.1999 and pursuing B.E (Mechanical) from Sathyabama Institute of Science and Technology. Author's major area of interest in the following subjects Thermal Engineering, Thermodynamics and IC.

Yarramsetti Nagendra was born at Andra Pradesh on 27.05.1997 and pursuing B.E (Mechanical) from Sathyabama Institute of Science and Technology. Author's major area of interest in the following subjects Thermal Engineering, Thermodynamics and IC.