FIRST RADIANT COOLED COMMERCIAL BUILDING IN INDIA – CRITICAL ANALYSIS OF ENERGY, COMFORT AND COST

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ABSTRACT

Radiation is an effective and proven way of heat transfer since ancient times; particularly radiant heating that has been in existence in Europe since several centuries. But radiant cooling is a relatively new application of radiation heat transfer and is being used widely in Europe and to some extent in the US since the last 15 – 20 years. Radiant cooling is highly efficient compared to regular air conditioning due to the high water temperatures used, minimized air system and also better quality of thermal comfort. Infosys, a premier IT company in India, in its quest towards energy efficiency and sustainability constructed the first radiant cooled commercial building in India in its campus in Hyderabad. Having a total built up area of about 24000 sqm., the most significant feature of this building is that it is split into 2 identical halves – one with conventional air conditioning (high efficiency and surpassing ASHRAE standards [90.1 baseline] by about 30%) and the other with radiant cooling. Both halves of the building had separate set of equipments and were extensively metered for accurate energy comparison. The building completed one year of operation and the results so far have been highly satisfactory. The radiant cooled half of the building has been consistently showing a significantly lower energy consumption compared to the conventional half. This paper discusses in detail the systems in the 2 halves of the building, the energy and comfort comparisons, and also the costs, which make the radiant cooling system the most promising new technology for air conditioning in India. This building serves as myth buster for a market where cost and risk have a high influence on any new technology implementation. The building has redefined the efficiency standards and will serve as a benchmark for the industry and be a global case study for radiant cooling technology with the most accurate comparisons of energy, comfort as well as cost!

THE IDEA

With a target of reducing the energy consumption by 50% in the new buildings of Infosys compared to 2007-08 levels, the approach to building and building systems design had to be radically different. Every aspect of building design right from the initial stages had to be perfect. Air conditioning being the highest energy consuming system in a building needed a new approach and therefore the idea of radiant cooling originated through discussions with global consultants. As with any new technology implementation, there was opposition from many stakeholders including consultants who were of the opinion that radiant cooling could never work in India. They were very skeptical of the new technology, the associated costs and risks involved. But with the backing of Infosys senior management and technical expertise of Rumsey Engineers, US, Rohan Parikh – Head of Green Initiatives at Infosys was able to drive in the idea of implementing the first radiant cooled commercial building in India. This resulted in one of the biggest experiments in air-conditioning, at the Hyderabad campus of Infosys. Since the technology was never before implemented in India, Infosys decided on making a clear comparison of radiant cooling with conventional air conditioning system so that it would pave the way for energy efficient technologies of the future. Thus, the building became a global case study for radiant cooling and a benchmark for comparing energy efficient technologies.

THE CONCEPT

The building (Software Development Block-1, Pocharam campus, Hyderabad) has a total built-up area of about 24000 sqm. distributed into east and west wings of 11600 sqm. each and a central wing of about 800 sqm. About 85% of the total building area is air-conditioned office area and the total occupancy of the building is about 2500.

The most significant feature of the building is that it is split into two symmetric halves. One half is cooled by conventional (but very efficient) air conditioning and the other half by radiant cooling. All parameters in the two halves – area, number of occupants, orientation, envelope and lighting – are similar and therefore the building is ideally suited for comparing two different technologies. To start with, the building has a highly efficient envelope with perfect orientation, double walls with insulation, insulated roof and efficient windows with appropriate shading to maximize natural light in the building and minimize heat ingress.

FIGURE 1: SDB-1 BUILDING, HYDERABAD

FIGURE 2: TYPICAL FLOOR PLAN OF THE BUILDING

The hourly profile of ambient temperature and relative humidity for Hyderabad is given below. The weather conditions show that there are different seasons in Hyderabad from hot dry in April-May to warm humid in July-August. This case study is a myth buster to prove that radiant cooling is effective in tropical climates.

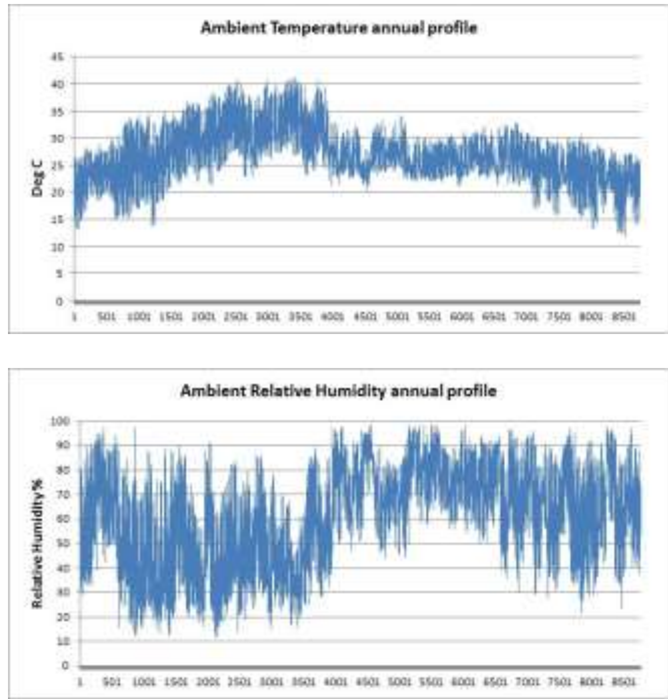

FIGURE 3: ANNUAL AMBIENT CONDITIONS FOR HYDERABAD

RADIANT COOLING PROCESS

Moving water is more efficient than moving air because of their physical and thermal properties. Water can carry 3,400 times the energy that air can carry for the same volume. This property of water is used to achieve maximum advantage in a radiant cooling system. Also, the natural manner in which the human body dissipates heat is mainly through radiation. This is the primary principle used in radiant cooling. Cold water flows through pipes embedded in the slab and cools the entire slab resulting in the slab surface being maintained at about 20 deg C. Cooling inside the office space is achieved when the cold slab absorbs the heat (radiation) generated by people, computers, lighting and other equipment which are exposed to the slab. Fresh air is supplied through an air system to maintain a healthy indoor environment, and also to control the moisture inside the office space. In other words, the sensible heat load is addressed by the cooled slab and the latent heat load is addressed by the Dedicated Outdoor Air System (DOAS).

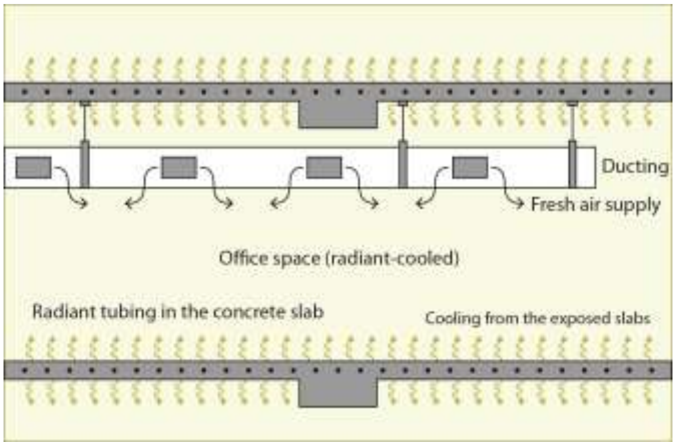

FIGURE 4: CROSS SECTION OF A RADIANT COOLED SPACE

FIGURE 5: CONCRETING OF SLAB WITH RADIANT PIPES

SYSTEM CONFIGURATION

A few salient features of the HVAC design of the building for both conventional and radiant systems are listed below:

Conventional air-conditioning system:

1. High efficiency chiller, pumps, AHUs and cooling tower, all with variable speed drives
2. Chilled water design temperatures: supply 7.8 deg C, return 15.6 deg C (high ΔT design)
3. Primary variable flow pumping system
4. Cooling tower approach: 2.2 deg C
5. AHUs with energy recovery wheel, evaporative cooling section and free cooling option for different ambient condition advantages
6. Low pressure piping and ducting design
7. VAVs for controlling air flow in office spaces.

Radiant cooling system:

1. The radiant slab was designed to give a cooling output of about 75 W/sqm, whereas the office loads were in the range of 50 W/sqm due to highly efficient design of the building and efficient lighting and computers.
2. High efficiency chiller, pumps, AHUs and cooling tower, all with variable speed drives
3. Chilled water design temperatures: supply 14 deg C, return 17 deg C
4. DX unit was provided with the DOAS for achieving dehumidification but this was replaced by chilled water coil in Aug 2011 as a retrofit to achieve higher efficiency in the system.
5. Primary variable flow pumping system
6. Cooling tower approach: 2.2 deg C
7. DOAS with energy recovery wheel for supplying dehumidified fresh air into the office spaces.
8. Low pressure piping and ducting design

RESULTS

Energy

The design of the building and the building systems was such the building was estimated to be about 40% more efficient than ASHRAE baseline building. The building was equipped with energy meters for each of the equipments of the air-conditioning system as well as the radiant cooling system so that individual equipment level efficiencies could be compared accurately. Also, the building features a state of the art Building Automation System to monitor and control the operation of the building systems accurately. The building achieved full occupancy in Feb 2011. The comparison results from the energy meters in the building are given below for the period April 2011 to March 2012.

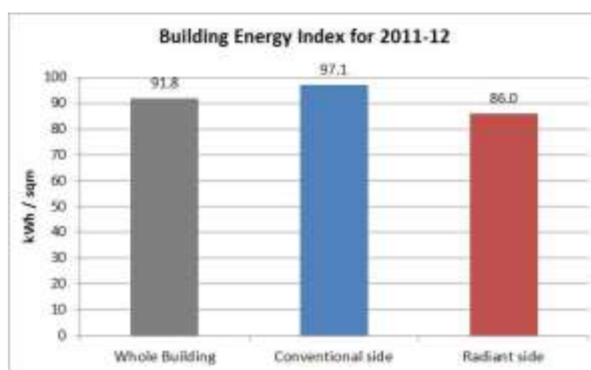

FIGURE 6: Annual Energy Index of the whole building including lighting, computers, HVAC and misc. loads

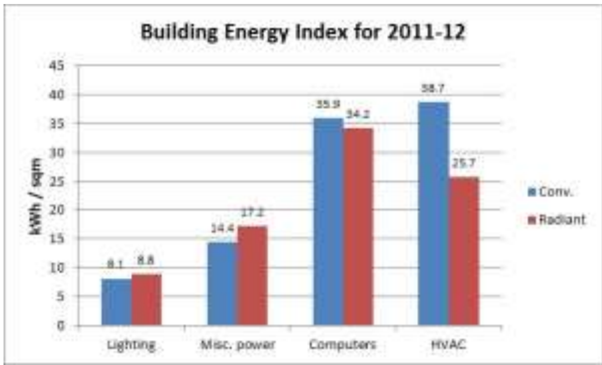

FIGURE 7: Annual Energy Index of different load components in the building

In 2011-12, the total consumption in the conventional air conditioning system was about 440000 units and in radiant cooling system was about 269000 units. The conventional air-conditioning energy index was recorded to be 38.7 kWh/sqm and the radiant cooling energy index was recorded as 25.7 kWh/sqm. So, the radiant cooling system was 33% lower in energy consumption compared to the conventional air-conditioning system for the period Apr 2011 – Mar 2012.

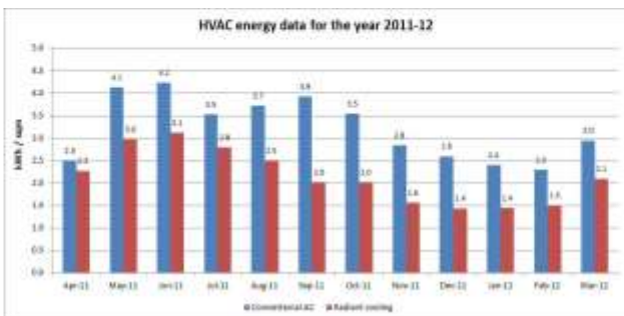

FIGURE 8: Month-wise Energy Index of conventional air-conditioning and radiant cooling systems

The distribution of energy in the HVAC system is given in the charts below:

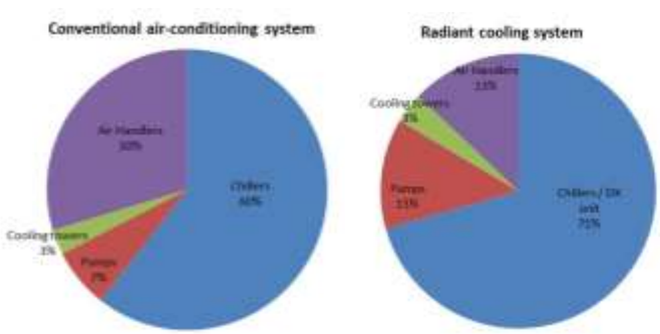

FIGURE 9: Component-wise distribution of HVAC energy in conventional and radiant systems

The distribution of energy shows that the contribution of air handling system is very low in the radiant cooling system compared to conventional air-conditioning system. The average chiller plant efficiency observed was in the range of 0.6 kW/TR for conventional air-conditioning system and 0.45 kW/TR for the radiant cooling system, though these vary through different seasons.

Comfort

The radiant cooling system inherently provides a healthier indoor air quality as there is no recirculation of air in the system. Treated fresh air provided to the occupants for maintaining healthy conditions as well as to remove moisture from the space. In principle, the radiant cooling system reduces the Mean Radiant Temperature (MRT) of the space since the slab is cooled. Therefore the perception of thermal comfort is expected to be higher for a radiant cooling system.

The building automation system ensures accurate monitoring and control of comfort parameters in the building such as temperature, RH and CO_2 levels. A detailed measurement and study by a team of researchers from the Technical University of Braunschweig, Germany highlighted that the perceived thermal comfort in the radiant side of the building was better than the conventional side. Another detailed monitoring of IAQ done by SGS India Pvt. Ltd. reported that the comfort parameters were within the permissible limits of ASHRAE 55-2004 and ASHRAE 62.1-2007 for most of the building. Also, the building has been operational with full occupancy for about 1.5 years and no major complaints have been recorded for radiant cooling.

Cost

One of the most important aspects while implementing any new technology is the capital cost involved. Higher capital cost usually means higher risk and therefore slow adoption by the society. In the case of radiant cooling, it was a completely different case where the capital cost of the system was slightly lower than the conventional air-conditioning system. A detailed breakup of the HVAC costs incurred for the building is given below: (All costs are in Indian Rupees - INR)

TABLE 1: COST COMPARISON OF CONVENTIONAL AND RADIANT COOLING SYSTEM

	Conventional	Radiant
Chiller	3145200	3145200
Cooling tower	1306400	1306400

HVAC low side works	22839000	15310000
AHUs, DOAS, HRW	5118200	2878900
Radiant piping, accessories, installation, etc.	0	9075800
Building Automation System	6184000	6584000
Total cost (INR)	38592600	38300300
Area (sqm.)	11600	11600
INR/sqm	**3327**	**3302**

The attractive costing is expected to be a major factor in driving the radiant cooling technology mainstream in India. One of the main objectives that Infosys set out to achieve through this building was to show that new and efficient technologies need not necessarily be expensive.

CONCLUSION

Radiant cooling technology is an emerging efficient technology in HVAC industry. It may be the technology of the future and may redefine the way cooling is done in India. The following points can be concluded from the Infosys case study:

- Radiant cooling system is easier to build since it requires fewer equipments and the overall cost of the system is slightly lower than the conventional air-conditioning system.
- Radiant cooling system occupies just one-third of the space compared to conventional air-conditioning system.
- The efficiency of radiant cooling system is about 33% better than a highly efficient conventional air conditioning system.
- Radiant cooling system provides a better indoor air quality and thermal comfort compared to conventional air-conditioning.

The radiant building in Hyderabad is considered among the most efficient buildings in the world for such climate conditions. Comparison of two cooling technologies at such scale has provided us an opportunity to make a clear conclusion of the advantages of radiant cooling. This building serves as the global case study for radiant cooling technology by providing accurate energy, comfort and cost data. The building has been awarded LEED India Platinum rating and redefines the benchmark for energy efficiency in India. The building was also featured in the Best Practices Guide for High Performance Office Buildings published by the Lawrence Berkeley National Lab, US. The data from this building paved the way for several buildings being currently designed with radiant cooling at Infosys and also other corporates in India. Through this building, Infosys hopes to lead by example and bring new efficient technologies mainstream, thereby starting an energy efficiency revolution.

REFERENCES

Infosys – Advanced Efficiency Building Hyderabad, India Schematic Design Narrative, Rumsey Engineers, Inc. Oakland, CA, 2009

Underfloor heating/cooling system Part 1: System Components, Technical Information 864.600E, REHAU AG, Germany

Infosys SDB-1 Hyderabad, Evaluation of Efficiency and User Comfort, Technische Universitat Braunschweig, Braunschweig, 2011

Vladimír Zmrhal, Jan Hensen and František Drkal, Modelling and Simulation of a room with a radiant cooling ceiling, IBPSA, Netherlands, 2003

Bjarne W Olesen, Radiant Heating and Cooling by Embedded Water based Systems, Technical University of Denmark, Denmark, 2008

Radiant Cooling research, Center for the Built Environment, University of California, Berkeley, 2010

SDB-1 Hyderabad Final Energy simulation report, Environmental Design Solutions, New Delhi, 2011

http://www.radiantcooling.org/ as accessed on 25th April 2012

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