Radiant Cooling: Designing an Energy Efficient Strategy

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In the current generation, many conventional cooling systems adopt air conditioning systems where the cooling load is purely convective. Traditional air conditioning techniques tend to blow air directly on people for more extended periods, which chills people instead of cooling them, making them less comfortable. So instead of blowing air directly on the people, why not control the temperature of walls. This methodology is known as radiant cooling.

All air conditioning systems are designed on convection mode only; the radiant cooling system provides heating and cooling by combining radiation and convection in a space. ASHRAE (The American Society of Heating, Refrigerating and Air-Conditioning Engineers) defines radiant systems as temperature-controlled surfaces where 50% or more of the design heat transfer occurs by thermal radiation.

Principle of Radiant Cooling

Circulating water is more efficient than circulating air because of its 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 a maximum advantage in a radiant cooling system. Also, the natural way the human body dissipates heat is mainly through radiation, as shown in the figure. These two criteria are utilized in radiant cooling.

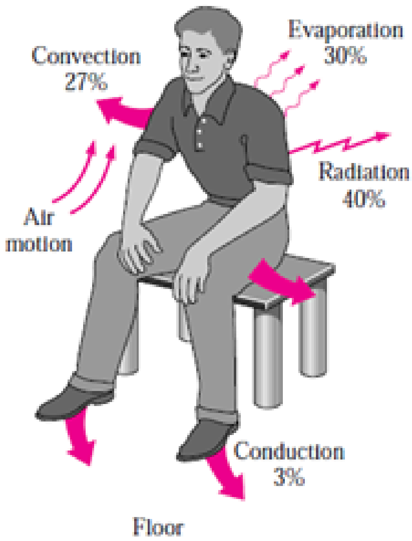

Fig. 19: Mechanisms of heat loss from the human body and relative magnitudes for a resting person

Coldwater flows through pipes embedded in the slab and cools the entire slab resulting in the slab surface being maintained at about 20 ℃. Cooling inside the 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 to control the moisture inside the office space. In other words, the sensible heat load can be addressed by the cooled slab, and the latent heat load can be addressed by the Dedicated Outdoor Air System (DOAS).

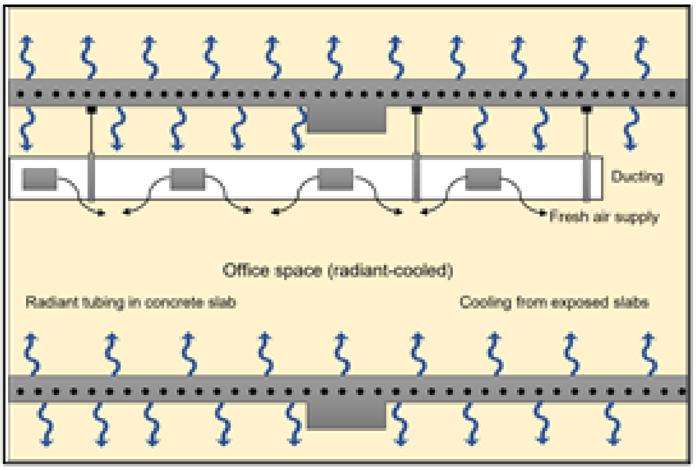

Fig. 30: Model of Radiant cooled space

Types of Radiant Cooling:

Depending on the position of the piping in the building, the radiant system is usually classified into three types:

- Embedded surface systems (pipes placed within a building layer (floor, wall, ceiling) which is isolated from the main building structure).
- Thermally activated building system (TABS) (pipes integrated into main building structure (ceiling, wall, floor)).
- Radiant panel system (pipes integrated into light-weight panels).

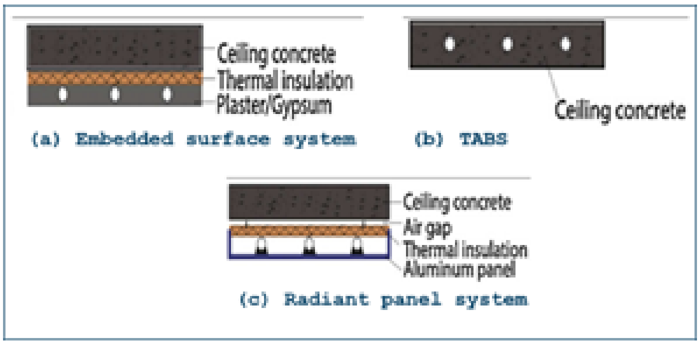

Fig. 21: Types of Radiant Cooling

Radiant v/s Conventional Cooling

At peak demand (during hot summer days when cooling in the building is generally needed), the conventional HVAC system uses about 37.5% of its power on tasks like the fan and motor for air distribution. The remainder of the loads is accounted for by the chiller and compressor units. It is important to note that only a fraction of this air supply is needed to ventilate a building and maintain excellent air quality properly. This realization is causing much research in developing new innovative technology involving radiant systems, which require less circulated air and less wasted energy from fans and motors. As discussed earlier, water has a much higher heat carrying capacity allowing for increased efficiency over all-air systems. Using this concept for a simple numerical example wherein a room is to be cooled having a total sensible load of 100 kW with a temperature difference of 14 ℃. When calculating the amount of power required to cool this space, a fan (for conventional air conditioning) comes out to be 14.2 kW, whereas for a pump (for Radiant Cooling) comes out to be 1.6 kW. It proves that the electrical demand of circulator water through the pump is only 11% of the fan motor to transfer the same amount of heat energy. It could save a lot of electricity.

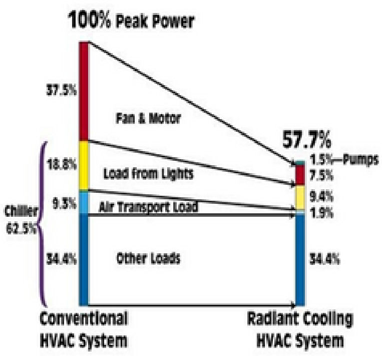

Fig. 22: Running power contributions for both the systems

the most significant feature of this building is that it is split into 2 identical halves: one with conventional air conditioning and the other with radiant cooling. Both building halves have a separate set of equipment and were extensively metered for accurate energy comparison. The building inaugurated this system in 2011, 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 than the conventional half.

This building serves as a myth buster for a market where cost and risk significantly influence 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, and cost.

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

Conventional air-conditioning system:

- High-efficiency chiller, pumps, (Air Handling Units) AHUs, and cooling tower, all with variable speed drives
- Chilled water design temperatures: supply 7.8℃, return 15.6 ℃ (high. T design).
- Primary variable flow pumping system.
- Cooling tower approach: 2.2 ℃.
- AHUs with energy recovery wheel, evaporative cooling section, and free cooling option for different ambient condition advantages.
- Low-pressure piping and ducting design
- (Variable Air Volume) VAVs for controlling airflow in office spaces.

Radiant cooling system:

The radiant slab was designed to give a cooling output of about 75 W/Sq.m, whereas the office loads were in the range of 50 W/Sq.m due to the highly efficient design of the building and efficient lighting and computers.

- High-efficiency chiller, pumps, AHUs, and cooling tower, all with variable speed drives.
- Chilled water design temperatures: supply 14℃, return 17 ℃.
- Ducting unit was provided with the DOAS for achieving dehumidification, but this was replaced by a chilled water coil in Aug 2011 as a retrofit to achieve higher efficiency in the system.
- Primary variable flow pumping system.
- Cooling tower approach: 2.2 ℃.
- DOAS with an energy recovery wheel for supplying dehumidified fresh air into the office spaces.
- Low-pressure piping and ducting design.

Energy Results:

The design of the building and the building systems were estimated to be about 40% more efficient than the ASHRAE baseline building. In 2011-12, the total consumption in the conventional air conditioning system was about 440000 units, and in the radiant cooling system was about 269000 units.

The conventional air-conditioning energy index was recorded to be 38.7 kWh/Sq.m, and the radiant cooling energy index was recorded as 25.7 kWh/Sq.m. So, the radiant cooling system was 39% lower in energy consumption than the conventional air-conditioning system for Apr 2011 – Mar 2012.

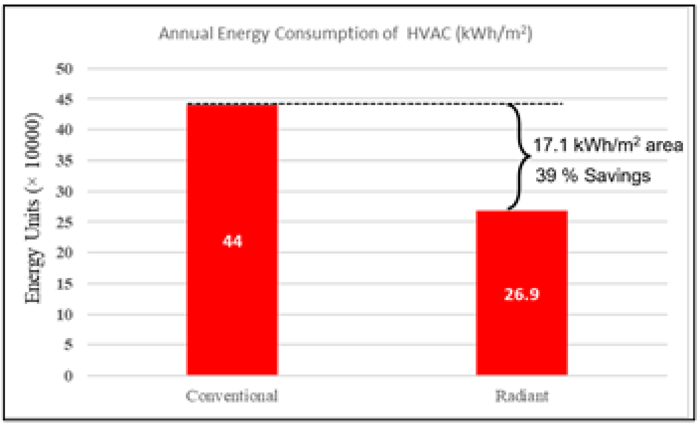

Fig. 23: Annual electricity consumption of the conventional system and the radiant cooling system

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 and removing 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.

Conclusion:

The above report concludes that radiant cooling can be used as an alternative to energy-efficient buildings. It is also a replacement for conventional cooling techniques. The radiant cooling technique also has zero (Ozone Depletion Potential) ODP and (Global Warming Potential) GDP, reflecting one of the best environmentally friendly cooling techniques. By controlling the surface temperature of walls or floors, a custom variable temperature can be set up depending on the loads in the buildings, reducing the chiller and energy costs. However, the initial setup costs are much more than conventional cooling, but they can be compensated with the running costs in running periods. Radiant cooling also provides better adaptive comfort to the occupants. In the coming years, where protecting the environment is of significant concern, radiant cooling can be a better cooling system. It is being implemented in various western countries and is assumed to spread in India as well.