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# Design of a Radiant Panel Cooling System for Summer Air Conditioning System

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**Abstract: The main objective of this investigation was to design and investigate a radiant panel cooling system on small scale building type (office) under the central Sudan climatic conditions so as to explore the benefits of radiant cooling systems over conventional air conditioning systems (Variable air volume systems). Transient heat conduction of building (finite difference method) was used to evaluate the simulation model. The computer program (Matlab) was used to calculate transient heat flow through the walls and ceiling (variable loads) of the conditioned space. Other heat loads of the conditioned space were determined by the standard ASHRAE method. The experimental verification was achieved by using a cooling system which consists of a water chiller unit, fan coil unit (ducted fan coil unit) and radiant cooling panels to evaluate the validity of the radiant cooling panel system. The experimental results showed that the ceiling radiant cooling panel system with dedicated outdoor air system saves power demand of 17.3% and 26.1% of VAV system in case if recirculation air and 100% fresh air are used in each respectively.**

**Keywords: Air Conditioning, Design of a Radiant Panel Cooling System.**

## Introduction

Achieving cooling in hot climates has long been a human preoccupation. For thousands of years, people have used varieties of architectural techniques (thermal mass, shading, strategically-placed vents, etc.) to adapt dwelling design and cultural practice to local climate conditions. After the industrial revolution, many of these techniques were adapted to the new requirements of large buildings [1].

The ceiling radiant cooling panel (CRCP) system was first introduced in some European countries and has become one of the popular design alternatives for space cooling in South West Europe where the climate is relatively mild and dries [2]. A controlled temperature surface is called radiant panel if 50% or more of the heat transfer is by radiation to the other surfaces seen by the panel [3].

## Basic concept of Radiant Panel Cooling Systems

Radiant cooling ceiling panels contain chilled water running through the pipes that are bonded to the non-visible side of the panels. The ceiling panels function as heat exchangers between the room air and the chilled water. The ceiling absorbs heat from the heat sources in a room and exchanges it with circulating chilled water. The chilled water is then pumped to a chiller, recooled and returned to the ceiling [4].

## Types of Hydronic Radiant cooling systems

There are various types of hydronic radiant cooling systems: metal ceiling panels, chilled beams, tube imbedded in ceilings, walls, and floors [5]. Figures 1, 2 and 3 show the various types of hydronic radiant cooling systems.

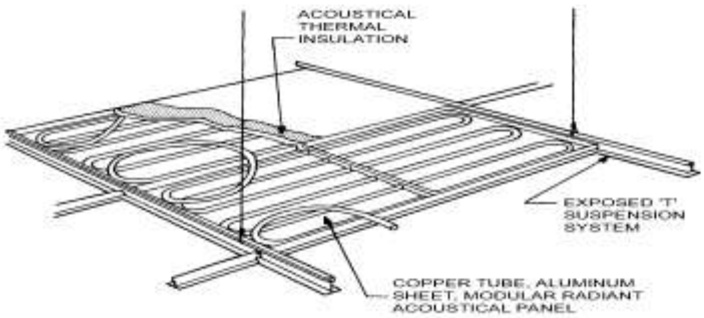


Figure 1: Metal ceiling panel bonded to copper tubing [3]

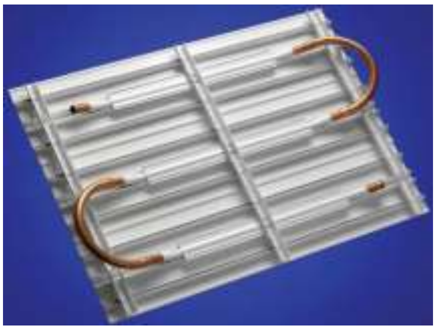

Figure 2:  Chilled beam panel [6]

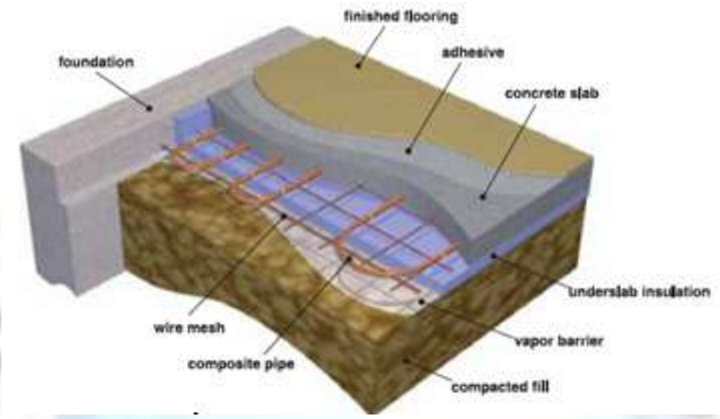


Figure 3:  Floor heating system [8]

**Basic Design data for conditioned Space**

Table (3.1) describes basic design data for the conditioned space. Figure 4 and 5 indicate layout and direction of the office building respectively.

Table 1:  Basic design data for the conditioned space

| Location | University of Khartoum, Faculty of Engineering (Latitude 15.7° N) |
|---|---|
| System description | Ceiling radiant cooling panel |
| Room size | 4.22m x 2m x 3.05m (height) |
| Occupancy level | 2 persons |
| Lighting | 2 fluorescent tube Lamps, (1)1200mm,T12 |
| Other assumption | All walls and ceiling are exposed to the sun, no moisture generation source except occupants, ventilation, and infiltration. Ambient temperature under floor air is 29°C |

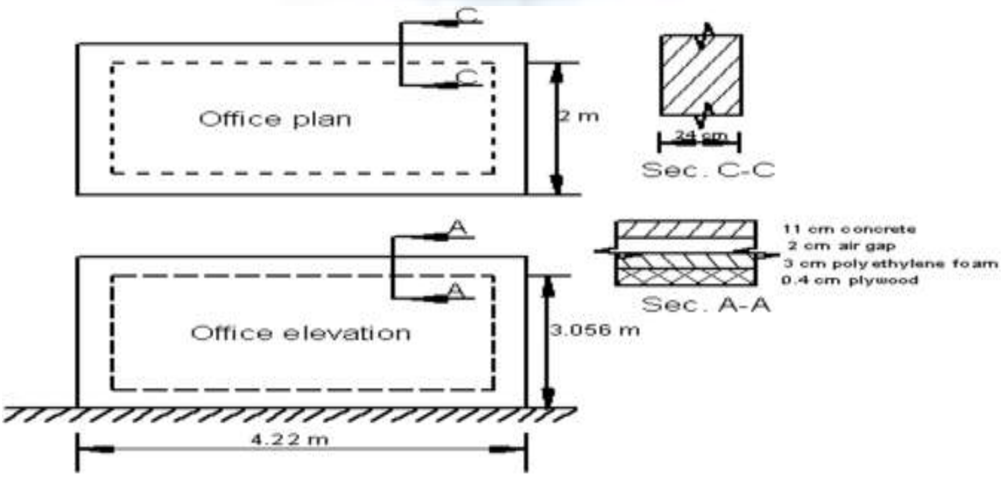


Figure 4:   **Layout of the office**

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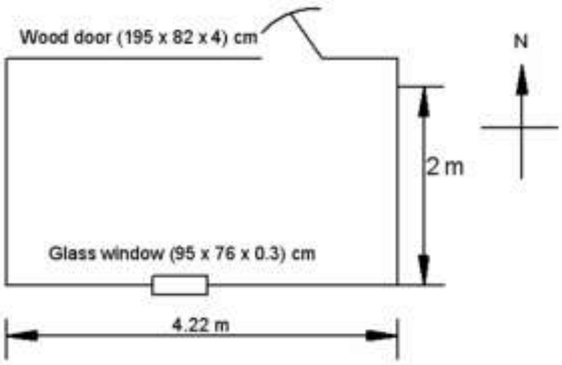


Figure 5: Orientation of the **office**

## Cooling load calculation

The cooling load of the conditioned space (3.5kW) was calculated by using computer program (Matlab) for transient heat flow through the walls and ceiling. Other heat loads were determined by the standard ASHRAE method. Then, the radiant cooling panel system was designed.

## Specification of ceiling Radiant cooling Panel

Four (1.3m x 1.05m) ceiling radiant cooling panels (aluminum sheet) are installed under the ceiling of the conditioned space. Each panel consists of thirteenth serpentine copper tubes fixed down side (Figure 6), and insulated with fiberglass at the top of the other side to prevent heat gains from the plenum space (between the roof and panel) as shown in Figure 7. Other descriptions of the panels are available in Table 2 and Figure 8.

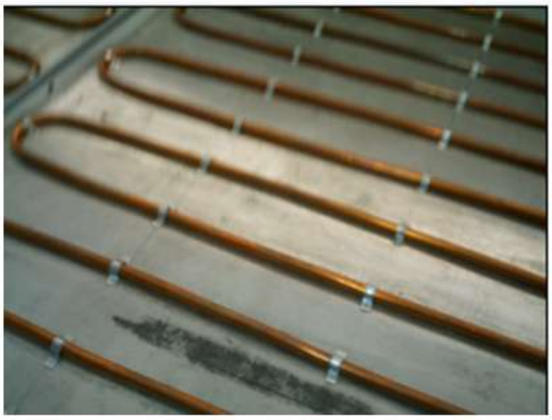

Figure 6. Aluminum sheet embedded with copper tube (CRCP)

Figure 7. CRCP top insulated

Table 1. Description of radiant ceiling panel's details

| | |
|---|---|
| **Length (m) of sheet** | **1.3** |
| **Width (m) of sheet** | **1.05** |
| **Thickness (m) of sheet** | **0.004** |
| **Outer tube diameter (m)** | **0.0127** |
| **Inner tube diameter (m)** | **0.0117** |
| **Tube spacing (m)** | **0.100** |
| **Panel insulation (fiberglass) thickness(m)** | **0.025** |

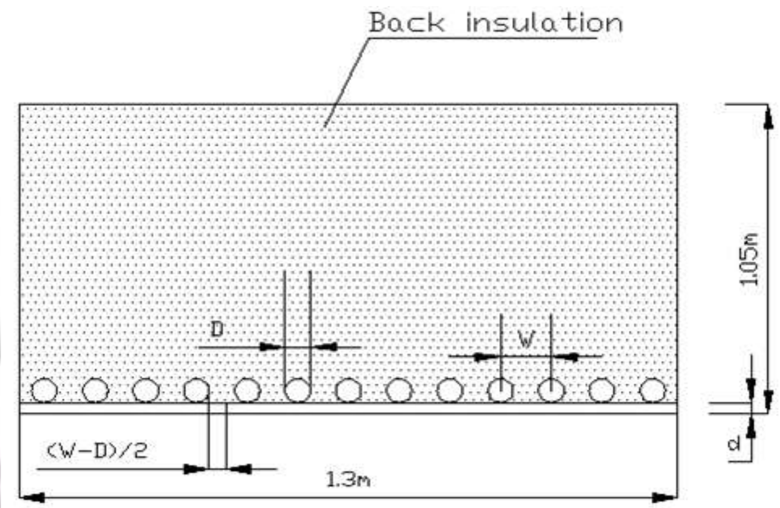


Figure 8. Cross section of the ceiling radiant cooling panel

**Model Space Condition**

The block diagram of the structured radiant ceiling panel with dedicated outdoor air system (DOAS) is shown in Figure 9. The chilled water passes to the fan coil unit to reduce the ambient temperature so as to supply an air temperature of 12$^{o}$C and then, enters the panel with 14.2$^{o}$C and exits with 16.8$^{o}$C. The chilled water is then pumped to a chiller, recooled and returned to the ceiling. The function of fan coil unit is to remove the latent and partial sensible heat load of the space.

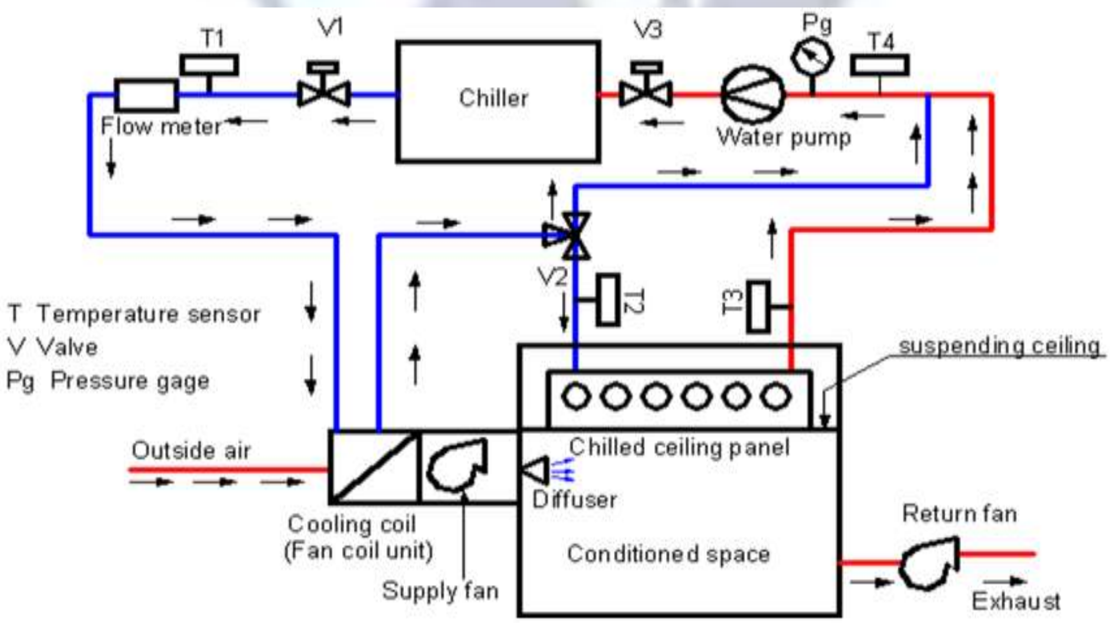


Figure 9. Schematic diagram of tested chilled ceiling panel with DOAS

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**Results**

The following, depict the results obtained after testing the system. From Table 3 it is found that the experimental results (DBT and RH of outside air) show relative variance when compared with design conditions. The variation is attributed to the fact that experiments were conducted during autumn season instead of summer season for which design conditions were set. On the other hand, the RH and DBT of inside air of experimental results show an increase of 4.42% and 3.4% in each respectively.

Table 3. Description of radiant ceiling panel's details

| | Design condition | | Average of experimental work | |
|---|---|---|---|---|
| Condition | R.H (%) | DBT ($^oC$) | R.H (%) | DBT ($^oC$) |
| Outside Conditions | 22.39 | 45 | 28 | 38.82 |
| Inside Conditions | 50 | 25 | 52.21 | 24.18 |

Figure 10, shows a comparison between CRCP/DOAS and VAV system for peak power demand through this study. It is clear that from this figure that the CRCP/DOAS system with recirculation air was found to save 17.3% energy over the VAV system with return air. On the other hand, 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.

The reason for this is that the CRCP/DOAS uses minimum supply air (86.8l/s) than VAV system (157.83 l/s) in case if recirculation air is used in each respectively. Also, the CRCP/DOAS uses supply air of (140l/s) than VAV system which uses (202.62 l/s) in case if 100% fresh air is used in each respectively. The other reason is attributed to the energy used by its pump (19.2W) which is less than by fan (40W) in VAV system.

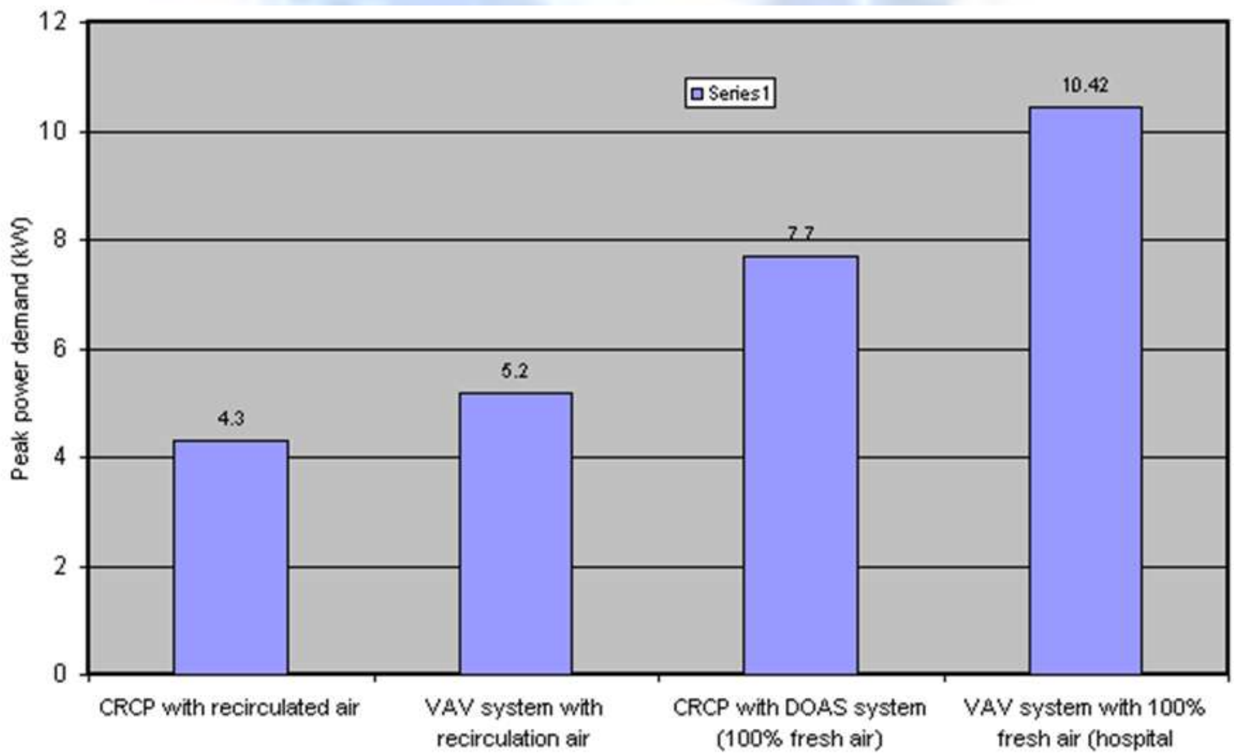


Figure 10. Comparison between CRCP/DOAS and VAV system for peak power demand

## Conclusion

From the study of the radiant panel cooling system according to Khartoum climatic conditions, the following conclusion can be drawn:

- The main objective of this research was to design and investigate a radiant panel cooling system in an office building under the central Sudan climatic conditions and to explore the benefits of radiant cooling systems over conventional air conditioning systems (VAV system).
- The main objective of this research was to design and investigate a radiant panel cooling system in an office building under the central Sudan climatic conditions and to explore the benefits of radiant cooling systems over conventional air conditioning systems (VAV system).
- The above comparisons (Figure 10) have shown that the CRCP/DOAS system saves 17.3% energy over the VAV system with recirculation air. On the other hand, 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.
- The reason for this is that the CRCP/DOAS uses minimum supply air (86.8l/s) than VAV system (157.83 l/s) in case if recirculation air is used in each respectively. Also, the CRCP/DOAS uses supply air (140l/s) than VAV system (202.62 l/s) in case if 100% fresh air is used in each respectively.
- The radiant panel cooling system is found to be very suitable for a hot and arid environment (Khartoum region) as shown in this investigation.

## References

[1]. Corina Stetui, "Radiant Cooling in US Office Buildings: Towards Eliminating the Perception Climate Imposed Barriers", Energy and Resources Group, University of California Berkeley, CA 94720, January 1998.

[2]. Jae-Weon Jeong, Stanley A.Mumma, " Simplified cooling capacity estimation model for top insulated metal ceiling radiant cooling panels", April 2004, pp. 2055-2072.

[3]. ASHRAE Systems and Equipment Handbook, New York 2000.

[4]. Invencys Company, "An Introduction to Invensys Radiant Ceiling Technologies" England, London, July 2002, pp.1-30.

[5]. Jae- Weon Jeong, Simplified Radiant Cooling Panel and Enthalpy Wheel Models For Dedicated Outdoor Air System Design, The Pennsylvania State University, The Graduate School College of Engineering 2004.

[6]. Hydro-Air Components. INC, "Linear Radiant ceiling panel" Hamburg, New York.
http://www.rittling.com/literature/catalogs/lrcp_0603.pdf

[7]. Financial Times Energy, Inc., "Design Brief Radiant Cooling" Boulder, Colorado.
http://www.energydesignresources.com/docs/db-02-radiantcooling.pdf

[8]. IPEX Manual of Modern Hydronics, Ontario 2004.