

STUDY THE PERFORMANCE OF A RADIANT COOLING SYSTEM USING WATER AS A MEDIUM IN A PROTOTYPE BUILDING

Submitted in partial fulfillment of the requirements for the award of Bachelor of
Engineering degree in Mechanical Engineering

By

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**INSTITUTE OF SCIENCE AND TECHNOLOGY (DEEMED TO BE
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Accredited with Grade "A" by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the Bonafide work of PALIKILA GOPINADH REDDY (Reg. No. 39150095), AMBATI CHIRANJEEVI (Reg. No. 39150005), who have done the Project entitled **"STUDY THE PERFORMANCE OF A RADIANT COOLING SYSTEM USING WATER AS MEDIUM IN A PROTOTYPE BUILDING"** Under our supervision of **Dr.S.P.VENKATESAN** from from December 2022 to April 2023.

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DECLARATION

I PALIKILA GOPINADH REDDY (Reg.No.. 39150095) and AMBATI CHIRANJEEVI (Reg.No.. 39150005) hereby declare that the Project Report entitled “**STUDY THE PERFORMANCE OF A RADIANT COOLING SYSTEM USING WATER AS MEDIUM IN A PROTOTYPE BUILDING**” done by me under the guidance of **Dr.S.P.VENKATESAN** is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering in Mechanical Engineering.



DATE: 26.04.2023

SIGNATURE OF THE CANDIDATE

PLACE: CHENNAI

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ABSTRACT

As the air temperature increases in hot and humid weather, a large amount of energy is needed to provide better cooling of residential and commercial buildings by air conditioning systems. Thus, to reduce energy consumption and provide good comfort cooling to the occupants in the indoor, the method of radiant cooling is a better choice. The concept of operation of this system is to provide a cooling effect to the room by absorbing sensible heat from the room which is acquired by the room through thermal radiation by passing water through the system. The energy consumption of this system is significantly lower than that of other conventional cooling systems.

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LIST OF ABBREVIATIONS

1. TABS - Thermally active buildings systems
2. TRCP - Thermally radiant cooling panel
3. CTS - Capillary tube system

CHAPTER-1

INTRODUCTION

Just similar to the ground temperature which keeps the walls of the basement keeps cooler and absorbs the heat from the room, a radiant system has the same effect providing even comfortable cooling to our living space. So the main objective of radiant cooling is to provide a cooler temperature in a building than the outer atmospheric temperature. This method can make the room cool by removing the sensible heat from the room. This method removes the heat from a room by using less energy which is energy efficient. This type of system uses water to cool or heat a living space. Many studies show that the energy consumption for air conditioning purposes have gone higher and higher these days and controlling this is very important to preserve global energy consumption [1].

Radiant cooling systems are the best alternatives for air conditioning systems to cool a building according to D. Petras, a researcher who concluded that radiant cooling is more effective and also uses less energy to give good thermal comfort [2]. A radiant cooling system in which pipes are embedded in the building structure like walls, floors or ceilings are called thermally active building systems. TABS can provide a good thermal comfort with less energy use. TABS are also less effective in cost and can be installed when the building is being constructed and can be in working condition as long as the building structure lasts [3]. According to Michal Krajcik the position of pipes embedded inside the building structure also play an important role in cooling outputs. Embedding the pipes underneath the building floor can reduce heat capacity by 63%. Apart from that, the spacing between the pipes and the temperature of water supply and the amount of time the water being supplied also plays an important role for the cooling effect [4]. Like this the use of radiant floor cooling extended from western and northern Europe to China, Korea, Thailand and US, with the widespread across the globe, the use of radiant floor cooling application has continued to improve. Radiant floor cooling systems are well protected from moisture condensation and the thermal comfort of the room will be good if the surface temperature of the floor is not less than 19 degree Celsius [5]. According to Chang-Ho-Jeong the usage of packaged air conditioners have increased as they have been using them as cooling systems. But the

increase in the usage of this system can lead to discomfort in convective cooling systems and also increase the amount of energy being consumed for cooling purposes. Therefore the best alternative for packaged air conditioners are Radiant cooling systems like TABS which are more comfortable and energy efficient are used in residential buildings in Korea [6]. Carlos Duarte mentioned that HVAC systems use about 44% of energy in the US buildings. Most HVAC systems use forced air systems typically variable air volume (VAV) in North America. Radiant cooling systems have more advantages over HVAC systems, enabling them to reduce the use of HVAC systems and help maintain equal and good thermal comfort [7]. So Radiant cooling systems have the ability to provide good thermal experience with less energy consumption for both cooling as well as heating purposes. In some places radiant heating systems are more popular than radiant cooling systems due to their need of usage and low cooling capacity [8]. So as the days are passing the usage of Radiant cooling systems are increasing rapidly across the globe and new ways for applying them for our daily use are emerging.

CHAPTER-2

LITERATURE SURVEY

S.NO	YEAR	AUTHOR AND JOURNAL NAME	INFERENCE
1.	2021	Daoming Xing , Nianping Li , Chen Zhang Per Heiselberg ; A critical review of passive condensation prevention for radiant cooling	The concept of passive condensation prevention for radiant cooling. The passive methods of creating super hydrophobic surfaces and adding cover shields to prevent condensation on radiant cooling surfaces are systematically reviewed.
2.	2020	AVES HUSAINY ; A glance on radiant cooling technology for cooling and heating a commercial space.	Process of thermal heat exchange being done.
3.	2021	Mohammad Shakeri , Jagadeesh Pasupuleti ; A brief review on radiant cooling panel with different chilled water pipe configurations.	Different types of water temperatures that can be used to flow in the pipes embedded in the building structure.

4.	2020	Michal Krajčíka, Ondřej Šikulab ; The possibilities and limitations of using radiant wall cooling in new and retrofitted existing buildings.	The system's suitability depends on the requirements such as avoiding interventions in the interior, exploiting thermal storage, or providing fast thermal dynamics. It is shown how various configurations of pipe location, material layers and thermal conductivity of the core allow compromising between the different performance indicators to design a system with the desired characteristics.
5.	2014	Kang Zhao, Xiao-Hua Liu, Yi Jiang ; Dynamic performance of water-based radiant floors during start-up and high-intensity solar radiation.	Types of radiant floors are examined: concrete core radiant floors and light radiant floors. Their variant dynamic behaviors during intermittent operation are illustrated, and the impact of transient solar radiation is determined through numerical calculation.
6.	2018	Chang-Ho-Jeong, Kwang-Woo Kim ; Feasibility of a Radiant Floor Cooling System For Residential Buildings With Massive Concrete Slabs.	Different types of water temperatures that can be used to flow in the pipes embedded in the building structure.
7.	2018	Xiufeng Panga, Carlos Duarte, Philip Haves a, Frank	Radiant slab systems have the potential to significantly reduce

		Chuangc ; Testing and demonstration of model predictive control applied to a radiant slab cooling system in a building test facility.	energy consumption in buildings. However, control of radiant slab systems is challenging. Classical feedback control is inadequate due to the large thermal inertia of the systems and heuristic feed-forward control often leads to unacceptable indoor comfort and may not achieve the full energy savings potential.
8.	2016	Kang Zhao, Xiao-Hua Liu, Yi Jiang ; Application of radiant floor cooling in large space buildings - A review.	In large space buildings such as airports, convention centers, atriums, and entrance halls, the envelope is dominated by glass façades and skylights; this indoor thermal environment is characterized by highintensity solar radiation and high-temperature internal wall surfaces.
9.	2017	Prabukumarghosh, A.Loganathan ; Implementation of radiant cooling systems in floors.	Radiant cooling system is such a type of alternative source used in the field of Air conditioning systems. Radiant cooling system can be implemented in floors, ceilings and pillars of multi storey buildings.

10.	2021	Fan Zhang ,Heinz-Axel Guo , Zhengxuan Liu, Guoqiang Zhang ; A critical review of the research about radiant cooling systems in China.	Radiant cooling (RC) systems have attracted more attention due to their advantages of better thermal comfort and higher energy saving potential compared with the conventional cooling systems in China.
11.	2022	Arefeh Hesaraki ,Nazmul Huda; A comparative review on the application of radiant low-temperature heating and high-temperature cooling for energy, thermal comfort, indoor air quality, design and control.	Radiant low-temperature heating (LTH) and high-temperature cooling (HTC) has become popular due to their high energy efficiency, thermal comfort, and improving indoor air quality.
12.	2018	Caroline Karmanna, Fred Bauman, Paul Raftery, Stefano Schiavona, Mike Koupriyanov ; Effect of acoustical clouds coverage and air movement on radiant chilled ceiling cooling capacity.	Thermally activated building systems have the potential to achieve significant energy savings, yet, the exposed concrete may also create acoustical challenges due to the high reflectivity of the hard surface.
13.	2021	Michal Krajčák , Martin Šimko , Ondrej Šikula , Daniel Szabó , Dušan	A radiant wall heating and cooling system with pipes attached to thermally insulating

		Petráš ; Thermal performance of a radiant wall heating and cooling system with pipes attached to thermally insulating bricks.	bricks was tested using climate chambers and a hotbox.
14.	2015	Chengchu Yan, Shengwei Wang* , Kui Shan, Yuehong L ; A simplified analytical model to evaluate the impact of radiant heat on building cooling load.	The effect of the radiative heat on the inner surface is ignored, which results in uncertainty of conductive heat gain calculation and may bring significant errors in cooling load calculation under some particular conditions.
15.	2004	Abdelaziz Laouadi ; Development of a radiant heating and cooling model for building energy simulation software.	E-cient radiant heating and cooling systems are promising technologies in slashing energy bills and improving occupant thermal comfort in buildings with low-energy demands such as houses and residential buildings.
16.	2017	Risto Kosonen ; Chilled Beams and Radiant Ceiling Systems.	Chilled beam systems are used for cooling, heating, and ventilating spaces, where good indoor climate quality and individual space control are appreciated.

17.	2017	Rajasekar Elangovan, Ashok Kumar, Ramachandraiah Alur ; Thermal Performance of Building Envelops.	Functional performance of a built-space results from an amalgamation of deterministic climate-building envelop interaction and probabilistic climate-occupant and building- occupant interactions.
18.	2017	Tong Yang, Croome, Matthew Marson ; Building Energy Management Systems.	By energy-conscious site planning to use natural unique physical features, microclimate can be modified to reduce or even eliminate the need of artificial conditioning.
19.	2018	Mi Su Shin, Kyu Nam Rhee, Sang Hoon Park, Myoung Souk Yeo, Kwang Woo Kim ; Enhancement of cooling capacity through open- type installation of cooling radiant ceiling panel systems.	Cooling radiant ceiling panel (CRCP) systems have been increasingly applied to modern buildings, owing to high thermal comfort, energy-saving potential, and integration with building design.
20.	2021	Vaibhav Rai Khare , , Ravi Garg , Jyotirmay Mathur , Vishal Garg ; Thermal Comfort Analysis of Personalized Conditioning System and Performance Assessment	he radiant systems consume less energy and provide better thermal comfort as compared to the conventional system, but the main drawback of radiant technology is inability to cater the latent load and condensation. This problem has engaged researchers to push

		with Different Radiant Cooling Systems.	their emphasis on Personalized Conditioning System (PCS).
21.	2022	Jun Shinoda , Ongun B. Kazanci , Katsuaki Hidari , Hiroki Watanabe , Yoshimi Takahashi , Shin-ichi Tanabe ; Improvements to the cooling capacity measurements of suspended radiant ceiling panels to prevent under-sizing.	The cooling capacity of a radiant panel is usually measured in a certified test chamber and the value obtained is provided by manufacturers for engineers to use for in calculations.
22.	2021	Xiaosong Gu , Mingliang Cheng , Xiaofeng Zhang , Zixin Qi , Jiang Liu , Zhenfeng Li ; Performance analysis of a hybrid non-centralized radiant floor cooling system in hot and humid regions.	Radiant floor cooling (RFC) systems are known for their energy efficiency and comfort. However, when a conventional intermittently operating RFC system is subjected to sudden increases in heat and moisture loads, condensation, difficulties with multi-zone temperature control, inadequate cooling capacity, thermal comfort degradation, and slow thermal response may occur.
23.	2021	Weixin Zhao ,* , Simo Kilpeläinen , Risto Kosonen, Juha Jokisalo , Sami Lestinen , Yuxin Wu , Panu Mustakallio ; Human response to thermal environment and	The purpose of this study is to analyze the human response to the indoor climate with two individually controlled convective and radiant cooling systems: a low velocity unit combined with radiant panel

		perceived air quality in an office with individually controlled convective and radiant cooling systems.	system (LVRP) and a personalized ventilation system combined with a radiant panel system (PVRP).
24.	2020	Rahul Khatria , Vaibhav Rai Khareb,, Hemant Kumara ; Spatial distribution of air temperature and air flow analysis in radiant cooling system using CFD technique.	The calibration of simulated model was done using the actual data and a hypothetical case of conventional cooling system has been evaluated with the help of TRNSYS for comparative analysis.
25.	2021	Helene Teufl, Matthias Schuss, Ardeshir Mahdavi; Potential and challenges of a user-centric radiant cooling approach.	The alternative user-centric strategy is intended to address this limitation by positioning vertical radiant panels closer to occupants and incorporating drainage systems for potential surface condensation.
26	2021	Minzhi Ye, Ahmed A. Serageldin, Ali Radwan, Hideki Sato, Katsunori Nagano; Thermal performance of ceiling radiant cooling panel with a segmented and concave surface: Laboratory analysis.	Radiant heating/cooling systems are thermally efficient and economically feasible alternatives to conventional ventilated air conditioning.
27.	2021	Ahmed A. Serageldin , Minzhi Ye , Ali Radwan ,	Radiant cooling/heating (RCH) panel systems have recently

		Hideki Sato , Katsunori Nagano ; Numerical investigation of the thermal performance of a radiant ceiling cooling panel with segmented concave surfaces.	received increasing attention because of their energy-efficient operation and improved comfort performance. Therefore, this study proposes a novel RCH panel with segmented concave surfaces.
28.	2017	Panu Mustakallio , Zhecho Bolashikov , Lauris Rezgals , Aleksandra Lipczynska , Arsen Melikov , Risto Kosonen ; Thermal environment in a simulated double office room with convective and radiant cooling systems.	The thermal environment in a double office room obtained with chilled beam (CB), chilled beam with radiant panel (CBR), chilled ceiling with ceiling installed mixing ventilation (CCMV) and overhead mixing total volume ventilation (MTVV) under summer (cooling) condition was compared.
29.	2020	Zhen Tiana,Liu Yang , Xiaozhou Wuc , Zhenzhong Guand ; A field study of occupant thermal comfort with radiant ceiling cooling and overhead air distribution system.	The main advantage of the RCF system for thermal comfort was found to be better comfort conditions than with conventional air conditioning at the same operative temperature range.
30.	2021	Dorit Aviv , Kian Wee Chen , Eric Teitelbaum , Denon Sheppard , Jovan Pantelic , Adam Rysanek	Radiant cooling-assisted natural ventilation is an innovative technical approach that combines new radiant cooling

		, Forrest Meggers ; A fresh (air) look at ventilation for COVID-19: Estimating the global energy savings potential of coupling natural ventilation with novel radiant cooling strategies.	technology with natural ventilation to increase fresh air delivery into buildings year-round with minimal energy cost and improvement of air quality.
31.	2019	Baisong Ninga , Youming Chenb , Hongyuan Jiacc ; Cooling load dynamics and simplified calculation method for radiant ceiling panel and dedicated outdoor air system.	Compared with all-air system, the cooling load dynamics for integration operation of radiant ceiling panel (RCP) and dedicated outdoor air system (DOAS) is more complex, and there is a lack of practical cooling load calculation method in current standards and guidebooks.
32.	2021	Seyedmostafa Mousavi , Behzad Rismanchi , Stefan Brey , Lu Aye ; PCM embedded radiant chilled ceiling: A state-of-the-art review.	Due to the upsurge in climate change and global warming as a consequence of population increase and economic growth, the energy demand for indoor air conditioning and comfort provision has rapidly grown over the past decade.
33.	2020	Baisong Ning, Youming Chen ; A radiant and convective time series method for cooling load	Traditional cooling load calculation theory and methods are based on the assumption that the room heat gains were

		calculation of radiant ceiling panel system.	only removed through convection by all-air system.
34.	2017	Caroline Karmann , Stefano Schiavon, Fred Bauman ; Thermal comfort in buildings using radiant vs. all-air systems: A critical literature review.	Hydronic radiant heating and cooling systems are considered as an energy efficient technology to condition buildings.
35.	2020	Muhammed A. Hassan, Omar Abdelaziz; Best Practices and Recent Advances in Hydronic Radiant Cooling Systems - Part II: Simulation, Control, and Integration.	There is an ever-increasing interest in radiant cooling systems (RCSs) due to their energy-saving 10 potential and improved indoor thermal environment in modern buildings.
36.	2019	Baisong Ning, Mengdi Zhang, Jiayu Li, Youming Chen; A revised radiant time series method (RTSM) to calculate the cooling load for pipe-embedded radiant systems.	Cooling load calculation can significantly affect the first cost, energy consumption, and performance of air-conditioning systems.
37.	2021	Prateek Srivastava, Yasin Khan, Mahabir Bhandari, Jyotirmay Mathur,	Radiant cooling system (RCS) has proven to be an energy efficient system for meeting a

		Ranaveer Pratap ; Calibrated Simulation Analysis for Integration of Evaporative Cooling and Radiant Cooling System for Different Indian Climatic Zones.	building's cooling requirements. RCS is energy efficient and provides better thermal comfort compared to conventional all-air heating ventilation air conditioning (HVAC) system.
38.	2017	J. Alstan Jakubiec ; Early- design sensitivity of radiant cooled office buildings in the tropics for building performance Riccardo Talamì.	The window solar heat gain coefficient and the façade window-to-wall ratio play a key role in this effort with respective values falling below or equal to 54% and 57%. The system set- point temperature has an increased importance for operational efficiency allowing high dry-bulb room temperatures ranging from 24.8 °C to 27 °C.
39.	2019	Marie Rugholm Krusaa , Ida Ørdu Hoffmann , Christian Anker Hviid ; Experimental investigation of integrated radiant ceiling panel and diffuse ceiling ventilation under cooling conditions.	This paper investigates experimentally the cooling performance of a concept, where the radiant ceiling is suspended from the hollow-core concrete slab and by ventilation supply in the plenum and the perforations of the ceiling tiles, ventilation air is distributed without ducts and air terminals to the occupied zone.

40.	2020	Hongshan Guoa, , Dorit Aviva , Mauricio Loyolaa , Eric Teitelbauma , Nicholas Houchois , Forrest Meggers ; On the understanding of the mean radiant temperature within both the indoor and outdoor environment, a critical review.	Mean radiant temperature is central to our understanding of the radiant heat exchange between the human body and surrounding environment.
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CHAPTER-3

AIM AND SCOPE OF THE PRESENT INVESTIGATION

This system surrounds the surface. By absorbing the heat, temperatures are reduced. Sensible heat gets removed from the conditioned environment giving the occupants thermal comfort in the room, which is accomplished by circulating water cooling in the floors via copper tubes. The room is recycled/cooled when cool water is allowed to flow through the pipes and the surface is cooled. While this process is taking place the surface temperature gets cooled resulting in absorption of sensible heat from the room and providing a cooler atmosphere and good thermal comfort. The aim is to give thermal comfort in the residential buildings as well as in the commercial buildings by reducing of the usage of energy consumption.

CHAPTER-4

METHODS

Many methods for radiant cooling systems have been introduced to give good thermal comfort in different climates and surroundings. Their application and working might differ from place to place. There are basically three types of radiant cooling system, they are

Thermally Active Building Systems (TABS)

Thermally Active Building system(TABS) uses thermally insulated pipes in the building structure like under the floor, inside the walls or even above the ceilings. This system uses thermal mass for heating and cooling, through which cooling is provided from the chilled surfaces.

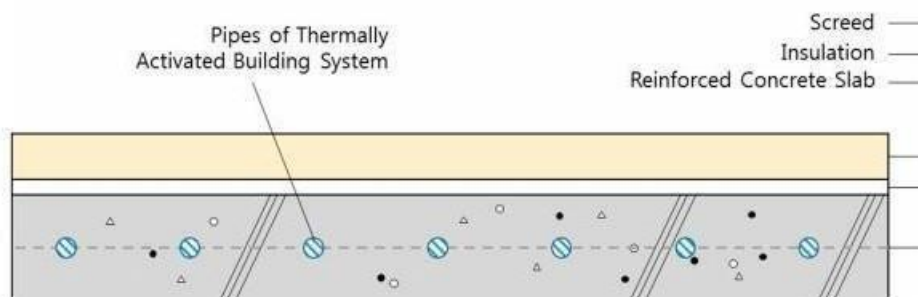


Figure- 4.1

Thermally Radiant Cooling Panel (TRCP)

In this system, integrated water pipes are provided in a radiant cooling system which is mostly covered above the ceiling. This type of system can be used in both new and already constructed buildings. But this system has a condensation problem which can be solved by allowing water with a temperature slightly higher than the dew point temperature.

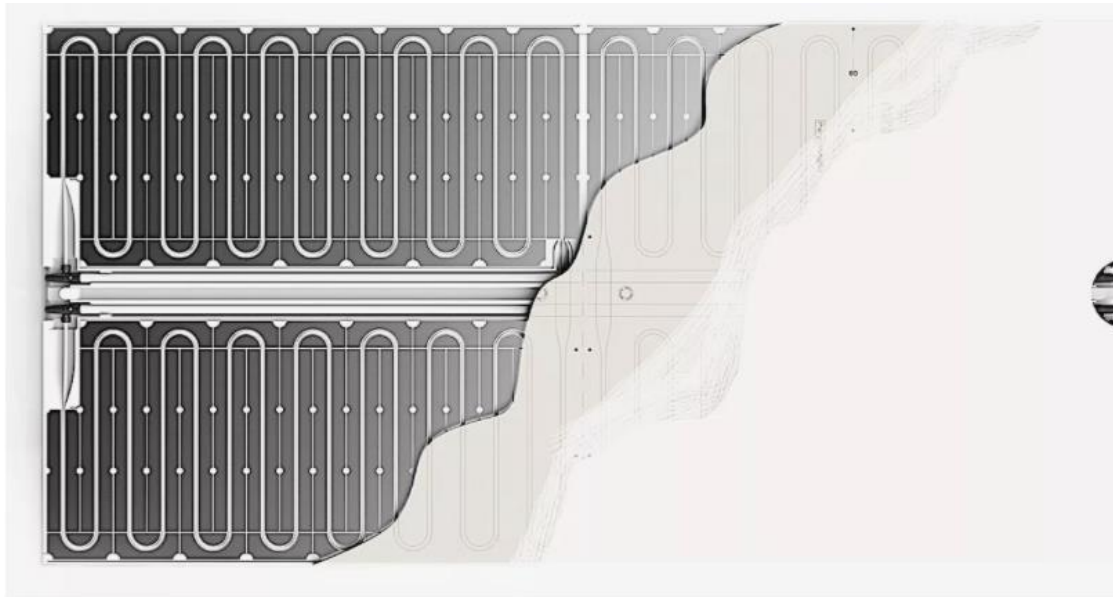


Figure- 4.2

Capillary Tube System (CTS)

This system consists of a cooling grids on which the capillary tubes are placed and are then covered using gypsum boards. It can also be built in the form of mat and can be placed on ceiling panels. The energy transfer in this system can be done without any noise.

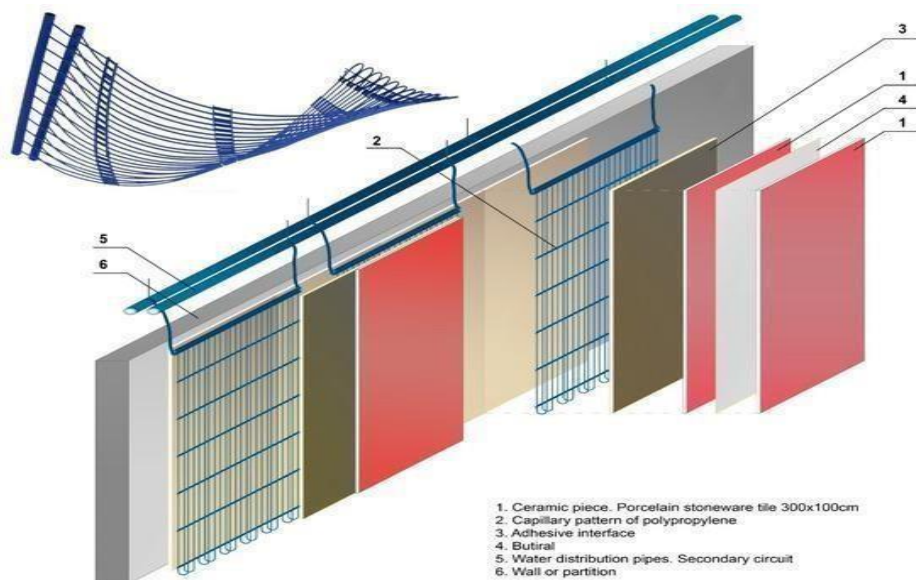


Figure- 4.3

MATERIALS

Copper Tubes

The copper tubes which can be used for cooling purposes are called ACR(Air conditioning and refrigeration) tubes. This kind of tubes come with a copper oxide layer inside of it and both ends of the tubes are closed to prevent it from moisture.



Figure- 4.4

Motor Pump

Motor pump moves fluids like liquids, gases etc. by a mechanical action. Motor pumps are classified into mainly three types 1.direct lift, 2.displacement and 3.gravity pumps. A motor pump moves the chilled water from the container tub to the copper tubes and again from copper tubes to container tub.



Figure- 4.5

Container tub

Container tub consists cold water and hot water. The copper tubes which are arranged under floor are connected to the motor pump and motor pump is attached to the container tub.



Figure- 4.6

Room Thermometer



Figure- 4.7.

WORKING PROCESS

- 1) While a building is being constructed the pipes(shown in fig.4.2.1) are laid under the floors , in walls or above the ceilings as (shown in fig.4.4.1).
- 2) The pipes are then covered with some concrete material under the floors as (shown in fig.4.4.2).
- 3) Then after the construction of the surface area, cool water is then allowed to flow in the copper tubes throughout the surface as (shown in fig.4.4.3).
- 4) The chilled water is taken from the container (shown in fig.4.2.3) which is forced out with the help of a motor pump(shown in fig.4.2.2).
- 5) Both the ends of the pipe are each connected to a motor pump which forces the water into the copper tubes and then again into the container.
- 6) Check the temperature of the room after sometime while the water is flowing through the pipes with a room thermometer(shown in fig.4.2.4).

CONSTRUCTION METHOD

- 1) Installation of pipes



Figure- 4.8

2) Cover the pipes with concrete material.



Figure - 4.9

3) Check the flow of water at both the ends of the pipe.



Figure- 4.10

PROTOTYPE MODEL



Figure- 4.11

CHAPTER-5

APPLICATIONS AND ANALYSIS

- These systems can be used to cool the interior of a buildings.
- It can be used in many places like schools, stores and offices.
- Radiant cooling tubes can be installed in floors, walls and ceilings of a room.
- The amount of energy being consumed for air conditioning purposes is saved.
- Electricity consumption can also be reduced as there are no moving parts in this system.
- Air and noise pollution can also be reduced, as it is an eco-friendly system.
- It is also more efficient when compared to forced flow systems.

CHAPTER-6

CONCLUSION

It can be concluded that the energy consumption for air conditioning purposes are increasing rapidly and the best way to reduce this is that installation of radiant cooling systems in a building infrastructure, as it can be an effective way to provide cooling in the living space. By installing them while the building is being constructed can be an easy way and also operational cost can be less. We can use this radiant cooling system for both cooling and heating purposes. By implementing this kind of systems for our daily usage purposes zero energy consumption can be achieved.

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6. Chang-Ho-Jeong, Kwang-Woo Kim ; Feasibility Of A Radiant Floor Cooling System For Residential Buildings With Massive Concrete Slabs.
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13. Michal Krajčık , Martin Šimko , Ondrej Šikula , Daniel Szabó , Dušan Petráš ; Thermal performance of a radiant wall heating and cooling system with pipes attached to thermally insulating bricks.
14. Chengchu Yan, Shengwei Wang* , Kui Shan, Yuehong L ; A simplified analytical model to evaluate the impact of radiant heat on building cooling load.

15. Abdelaziz Laouadi ; Development of a radiant heating and cooling model for building energy simulation software.
16. Risto Kosonen ; Chilled Beams and Radiant Ceiling Systems.
17. Rajasekar Elangovan, Ashok Kumar, Ramachandraiah Alur ; Thermal Performance of Building Envelops.
18. Tong Yang, Croome, Matthew Marson ; Building Energy Management Systems.
19. Mi Su Shin, Kyu Nam Rhee, Sang Hoon Park, Myoung Souk Yeo, Kwang Woo Kim ; Enhancement of cooling capacity through open-type installation of cooling radiant ceiling panel systems.
20. Vaibhav Rai Khare , , Ravi Garg , Jyotirmay Mathur , Vishal Garg ; Thermal Comfort Analysis of Personalized Conditioning System and Performance Assessment with Different Radiant Cooling Systems.
21. Jun Shinoda , Ongun B. Kazanci , Katsuaki Hidari , Hiroki Watanabe , Yoshimi Takahashi , Shin-ichi Tanabe ; Improvements to the cooling capacity measurements of suspended radiant ceiling panels to prevent under-sizing.
22. Xiaosong Gu , Mingliang Cheng , Xiaofeng Zhang , Zixin Qi , Jiang Liu , Zhenfeng Li ; Performance analysis of a hybrid non-centralized radiant floor cooling system in hot and humid regions.
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24. Rahul Khatria , Vaibhav Rai Khareb,, Hemant Kumara ;
Spatial distribution of air temperature and air flow analysis in
radiant cooling system using CFD technique.
25. Helene Teufl, Matthias Schuss, Ardeshir Mahdavi; Potential
and challenges of a user-centric radiant cooling approach.
26. Minzhi Ye , Ahmed A. Serageldin , Ali Radwan , Hideki Sato
, Katsunori Nagano; Thermal performance of ceiling radiant
cooling panel with a segmented and concave surface:
Laboratory analysis.
27. Ahmed A. Serageldin , Minzhi Ye , Ali Radwan , Hideki Sato ,
Katsunori Nagano ; Numerical investigation of the thermal
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