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WHITE PAPER ON RADIANT COOLING

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Introduction

Radiant Cooling Technology is based on the physical principle that bodies with varying temperatures exchange thermal radiation until an equilibrium is achieved. In addition to substantially lowering energy and peak load costs for space conditioning and ventilation, radiant systems enjoy other advantages over other air systems from energy and wellness point of view such as:

- Delivering energy at small temperature differences from room air makes it possible for chillers (and heating systems) to operate more efficiently.
- Less energy required to transport heat transfer medium (water) when compared to conventional HVAC where air is used.
- Better indoor air quality (because ventilation air is not recirculated and there are no wet surface cooling coils, thereby reducing the likelihood of bacterial growth).

Below are few salient features of water cooling the structure as compared against air conditioning the space:

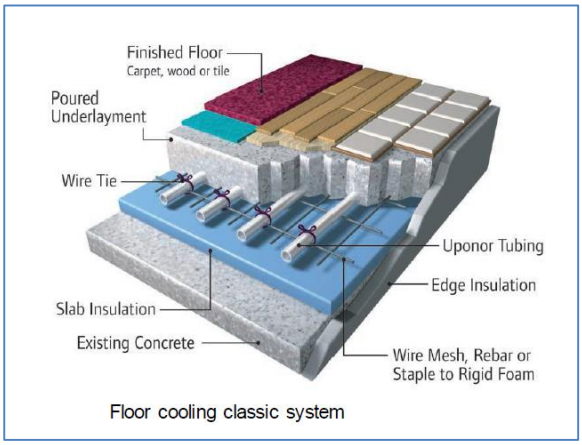
- Accounting for the pressure drop involved in pumping water throughout a building, a hydronic system can transport a given amount of cooling with less than 10 percent of the energy required to deliver cool air with fans.
- The ventilating function is separate; the volume of air moved and the components to move it can be roughly five times smaller. Fan power is saved and ducts can be smaller.
- No noise or little air disturbance during operation and provide a more uniform thermal environment compared to mixed ventilation systems.

For cooling, it is important to maintain the temperature of the outer surface of the tubing that carries cooling water above the dew point to avoid condensation. This constraint dictates that buildings be well air-sealed and that in highly humid areas, ventilation air undergo some dehumidification. It also means that the cross-sectional areas of cooling surfaces need to be big enough that adequate cooling energy can be delivered at small temperature differences. To manage indoor humidity levels and air quality, a separate ventilation system to supply treated fresh air is needed.

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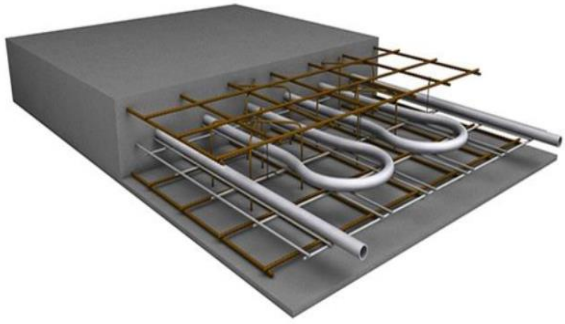
Types: Description, Pros and Cons

(a) Floor Radiant Cooing



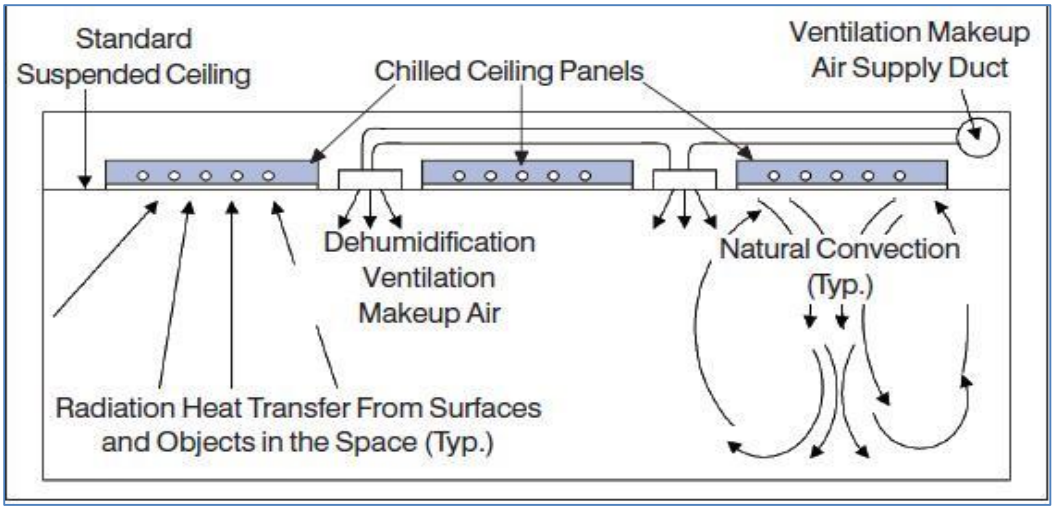
Floor cooling classic system

(b) Slab Radiant Cooling



- Pipes embedded in the slab along with reinforcements

(c) Ceiling Panels Radiant Cooling



Manifolds (as shown in below image) are used to ensure proper zoning of radiant piping and the same are needed to be easily accessible for maintenance or future repairs, as all connections are made at the manifold. Also to achieve maximum efficiency and output from the radiant system it is necessary to keep the supply and return lines as short as possible, and hence the manifold closer to the zone.





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Sr No	Parameters	Slab	Floor	Ceiling Panels
1	**Description/ Installation Methodology**	Pipes are embedded in the slab during construction. They deliver cooling through the cooled slabs and is also known as thermally activated building systems (TABS).	Radiant pipes are laid in 50mm screed above slab. Tiles can be laid above the pipes without having any loss in cooling effect.	Mats of small, closely spaced tubes are embedded in plastic, gypsum or metallic panels and are installed below soffit which acts as a false ceiling. These panels are interconnected to allow chilled water flow.
3	**Advantages**	a) Offer more significant thermal mass and therefore can take better advantage of outside temperatures swings. b) Lower maintenance than all other radiant systems.	a) Comfort conditions are achieved in lesser time than all other systems. b) Piping can be laid effectively as per furniture layout. C) Less thermal inertia	a) Faster temperature control and flexibility. c) Very suitable for retrofits as they can be attached to any ceiling. d) Quickly adjust to changes in outdoor temperature
4	**Disadvantages**	a) Cooling effect is divided in space above and below slab. b) Cannot have false ceiling; if done half of the cooling benefits will be lost c) More thermal inertia d) Least flexible for furniture layout	a) Not suitable in case of shorter lease periods b) Floors have furniture, coverings and furnishings that decrease the effectiveness of the system.	a) Due to water leakages and condensation issues, requires frequent maintenance b) Less flexible false ceiling c) Low thermal mass d) Higher initial costs and longer payback period
5	**Best Applications**	a) Buildings with high-performance envelopes b) Moderate Climates c) Use with natural ventilation and/or low-energy cooling or heating sources. d) Captive buildings	a) Recreation halls* b) Indoor game* courts *should not have carpets (else 15% reduction in cooling effect)	a) Buildings with greater variation in skin loads b) Buildings with spaces having highly variable internal loads c) Mixed-mode buildings with zoned or seasonal operation

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Analysis

A typical commercial office building of 260,000 sqft is considered for life cycle costing (radiant systems compared with conventional system). Below table illustrates the findings:

Sr No	Parameters	Slab	Floor	Ceiling Gypsum Panels	Ceiling Metallic Panels
1	Cost, Rs/sqft	125	220	350	450
2	Cooling capacity W/sqm	90	75	75	120
3	Need of additional conventional system to take room sensible load	No	No[1]	No[1]	No
4	Need of additional conventional system to take room latent load	Yes	Yes	Yes	Yes
5	Effect on construction timeline	Yes	No	No	No
6	Capital Investment in Owners Scope	Yes	Can be avoided	Can be avoided	Can be avoided
7	Typical Surface Area	Up to 100% of Floor Area	Up to 100% of Floor Area	50-70% of ceiling area	50-70% of ceiling area
8	Constraint on having carpet	Yes	Yes	No	No
9	Conventional System Capex, Rs (Cr)	7.3	7.3	7.3	7.3
10	Conventional System Opex, Rs (Cr)	3.1	3.1	3.1	3.1
11	Hybrid System Capex, Rs (Cr)	9.6 Conv.:6.3 Rad.:3.3	10.3 C:6.4 R:3.9	12.8 C:6.4 R:6.4	14.5 C:6.3 R:8.2
12	Hybrid System Opex, Rs (Cr)	2.2	2.2	2.2	2.2
13	Capex Differential, Rs (Cr)	2.3	3.1	5.5	7.2
14	Opex Differential, Rs (Cr)	1.0	0.9	0.9	1.0
15	Payback, Years	2.4	3.4	6.1	7.6

[1]Conventional system to take sensible load will be require if the sensible load exceeds 75w/sqm

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A radical study for typical School was also done where a school with radiant slabs (without chilled water) with UGT water circulated through slabs and cooling tower (space at 28 degC) was evaluated, as follows:

Parameter	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Staff Offices and Selected Labs	24 (Conv)	24 (Conv)	24 (Conv + Rad)	28 (Rad)
Classrooms and other common areas	Unconditioned	24 (Conv)	28 (Rad)	28 (Rad)
Tonnage with DX	138	495	112	0
Tonnage with Radiant	0	0	91	91
Capex , Rs	4,140,000	14,850,000	16,100,000	12,740,000
Opex, Rs	1,324,800	4,752,000	1,293,600	218,400
Capex Differential, Rs	0	10,710,000	11,960,000	8,600,000
Opex Differential, Rs	0	(3,427,200)	31,200	1,106,400
Payback (in years)	-	-	-	**7.77**

Notes:

- *Conv – Split units (5*Inverter or VRVs)*
- *The above scenarios compare the current situation (only a few office air conditioned, while rest of the school not air conditioned) with situations where:*
  - *the full school is air conditioned (for 24 degrees) (Scenario 2)*
  - *only few offices and labs air conditioned (mix of conv and radiant slabs#) but rest of the school also provided with radiant slabs (for 28^ degrees) (Scenario 3)*
  - *full school with radiant slabs (for 28 degrees)(Scenario 4)*

^This also touches on the debated rigidity of human comfort temperature (24 degrees). Having entire school at same temperature, comfortable, assisted with Fans might be a more natural environment for children.
#The radiant slabs are not cooled by chilled water, rather it is cooled by the treated water circulated through cooling towers (that's why such a low energy cost).

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Recommendations

- Based on the above analysis, it is **recommended** to consider Slab or Floor radiant cooling systems in captive use projects, where ID is available in advance.
- The Floor radiant cooling system can also be **recommended** for tenant fit out commercial buildings, where the scope of installing the same can be placed with the tenant – noting that the payback (3.4 years) is less than the typical lease duration (5 years).
- (Note) The factors such as construction timeline, constraints of having floor carpets and false ceiling, etc. should be taken into consideration while opting for slab radiant cooling.
- Frequent modifications in furniture layout or short lease durations are **not recommended** for this system.
- Ceiling panels are most suitable from better temperature control, operational savings and flexibility point of view, but are **not recommended** due to their high capital cost and a longer payback. This system needs to be explored further on optimizing the capital cost.
- A typical School with radiant cooling in slabs (without chilled water), but cooled via cooling towers (space at 28 degC) also seems to be an **impressive option** for implementation

References

1. First radiant cooled commercial building in India – critical analysis of energy, comfort and cost- http://portal.aeecenter.org/files/newsletters/ESMS/Sastry.pdf
2. Design Brief Radiant Cooling- http://www.oorja.in/wp-content/uploads/2016/09/EDR_DesignBriefs_radiantcooling.pdf
3. Everything about radiant cooling- http://www.oorja.in/what-is-radiant-cooling/