White Paper

Radiant ceilings with mass connection – functional principles and benefits

Tailor-made solutions for indoor climate

BARCOL-AIR by Swegon

White Paper

Radiant ceilings with mass connection – functional principles and benefits

Thermal management of the room perimeters, in particular the concrete ceiling, can play an important role in the energy efficient running of a building. When it comes to incorporating this "mass connection" into the operation of radiant ceilings, an in-depth understanding of the functional principles of the various models on the market is essential.

Barcol-Air has sound knowledge of mass connection, gained through its in-house climate laboratory equipped with a solid concrete ceiling, where numerous measurements are performed with different products and installation situations: this White Paper describes the key findings.

The White Paper addresses the following questions:

- Mass connection – definition and benefits
- Functional principles of different systems
- Which systems are well suited to mass connection, and which less so?
- Correct operation of a radiant ceiling with mass connection

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Introduction

Energy efficiency and the sustainable management of buildings has become a key consideration in building design. Operating radiant ceilings energy efficiently naturally brings cost advantages but in addition to that, legislators in certain countries such as Switzerland, require the building mass to be integrated to a greater extent into the energy management of a building.

Various radiant ceiling systems allow connection of the mass to the building's climate control concept. The different solutions require analysis and categorisation. This White Paper aims to provide impetus for this and answer the following questions:

- What is the definition of mass connection?
- What are the benefits of radiant ceiling systems with mass connection?
- How do the different systems on the market work, and what are their pros and cons?
- How should radiant ceilings with mass connection be operated in order to realise their full potential?

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Mass connection – the building envelope as an energy store

All bodies have heat capacity – i.e. the capacity to convert energy into heat. In addition to the thermal coefficient (c) of each substance or mixture of substances, which can be looked up in tables, the degree of conversion of energy (Q) into heat (T) is also composed of the mass (m) of a body. Bodies with high mass therefore heat up less than those with low mass, with the same energy input.

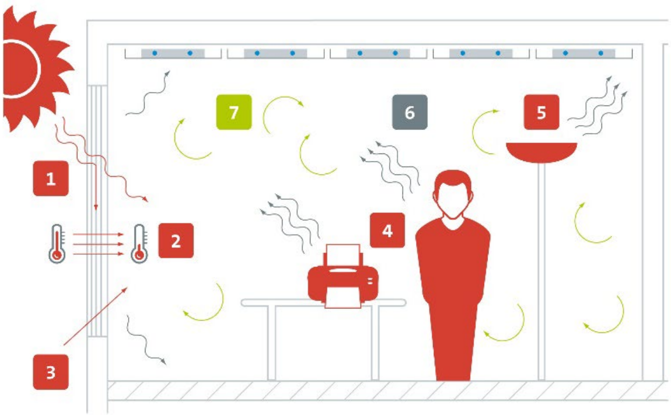
$$\Delta T = \frac{Q}{m * c}$$

Buildings with masonry walls and ceilings made entirely of concrete heat up more slowly with high heat loads than buildings with walls constructed of metal, wood, gypsum and/or glass. The mass of buildings is therefore continually being increased, in order to handle short hot spells or cold snaps without additional climate control. Solidly constructed buildings, such as old churches or bunkers, tend to remain at a stable temperature.

However, once the energy is inside the concrete, e.g. after a hot spell lasting a few days, it cannot easily be drawn out again simply by the air movements in the room. However, the building mass – in our case, the concrete ceiling – can be used to store loads during the day and to dissipate them at night when energy is cheaper and the outside temperature is lower. In this way, refrigeration units can be run more efficiently or buildings can even be tempered via free cooling.

How do conventional radiant ceiling systems work without mass connection?

The required cooling capacity of a radiant ceiling is normally calculated for the worst situation that can occur in a normal year. In other words, assuming the maximum solar radiation on a particularly hot day with the maximum likely number of occupants in the office space. The cooling capacity is then calculated in an assumed state of equilibrium – often 26 °C – together with the resulting lower temperature of the water and supply air.

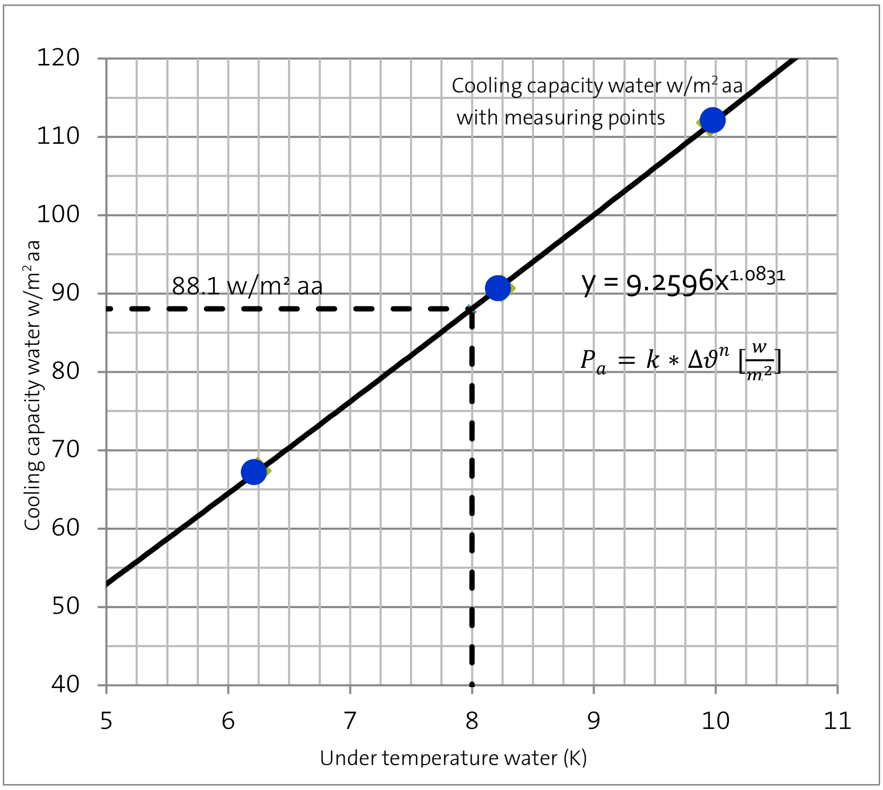


Thermal loads

1 Solar radiation
2 Transmission
3 Ventilation losses
4 Persons, office technology
5 Lighting

Heat exchange

6 Radiation
7 Convection



Static water cooling capacity
Baseline data for graph

System: metal cooling sail with steel ceiling panel
Activation (water system): copper tube coil on aluminium conducting rails at a distance of 100 mm, glued onto fleece, without acoustic mat
Supply air flow: none

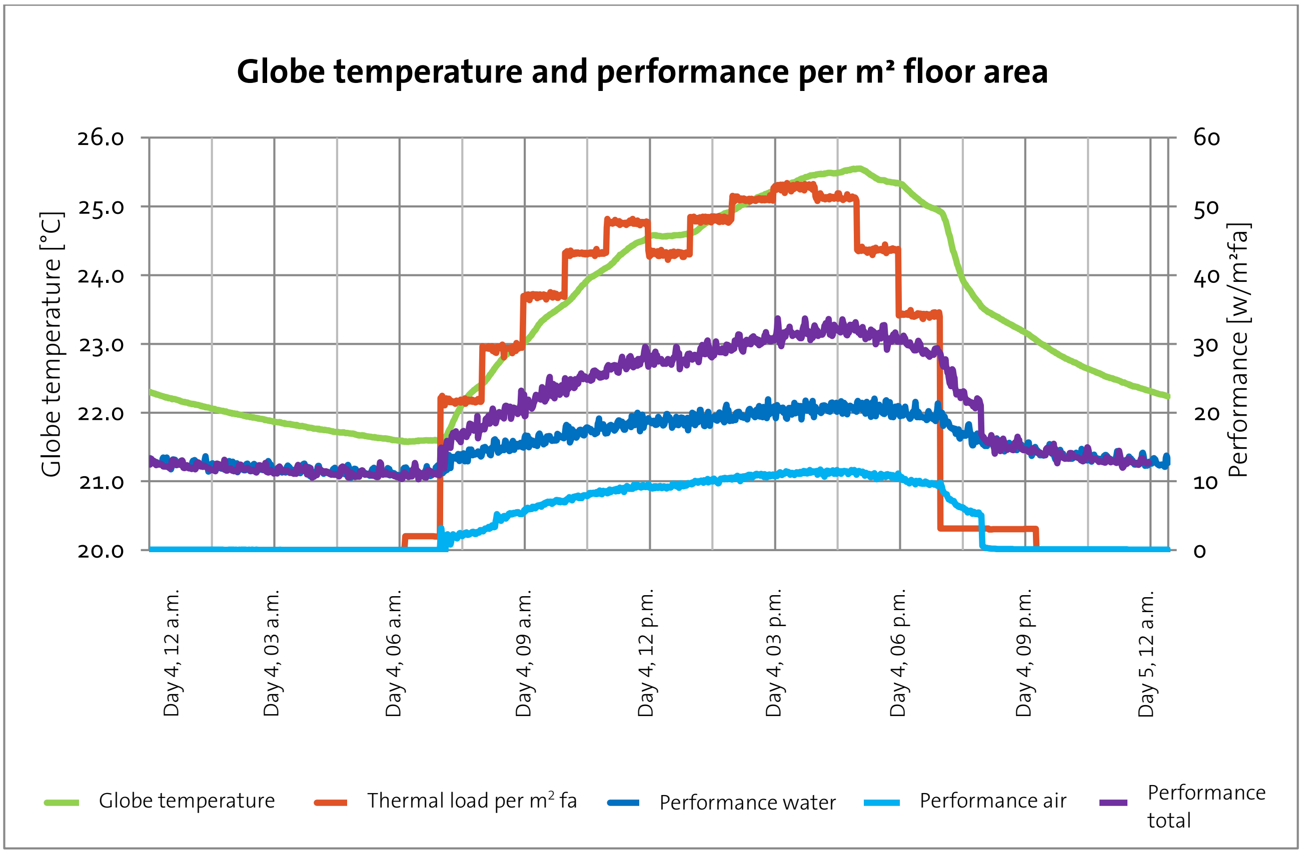
How do radiant ceiling systems work with mass connection?

It is necessary to take into account the fact that, when the room temperature is highest, a certain proportion of the room heat also passes into the concrete ceiling and masonry walls, as soon as these are colder than the room. This proportion can be increased by additionally pre-cooling the concrete at night. In addition, the temperature in a real room always fluctuates within a certain range over the course of the day, e.g. between 21 °C at the start of work up to a maximum of 26 °C.

Concrete after night cooling

Concrete at the end of the day, discharge

In real conditions, therefore, room temperatures are dynamic and fluctuate through the day. The actual capacity of the radiant ceiling at the time of maximum load then only needs to be around 70 to 80 % of this maximum load. A prerequisite for this is that the concrete ceiling must not be disconnected from the room – energy exchange must be possible through the exposed concrete surfaces. This is above all the case with chilled sails.



What are the benefits of radiant ceiling systems with mass connection?

Energy efficient

Provided that a radiant ceiling with mass connection is operated and controlled correctly, it can be run exclusively at night and in free cooling mode for most of the year (excluding hot spells). The reduced heat loads outside of a hot spell can then be stored by the building mass until the night and partially dissipated during the day by the air flow (which is a hygiene requirement).

To use free cooling, the outside temperature must be 2 K below the flow temperature of the water. Even during hot spells, this means that the energy used during the day is considerably reduced compared with conventional systems and the COP[1] of the refrigeration unit is much higher at night than during the day.

Environmentally responsible

Increasing the COP of the refrigeration unit considerably reduces the electric portion of the refrigeration process. As soon as it is possible to proceed with free cooling, no electrical energy is needed for refrigeration besides the pump output. This leads to a dramatic reduction in CO_2 emissions.

Cost efficient

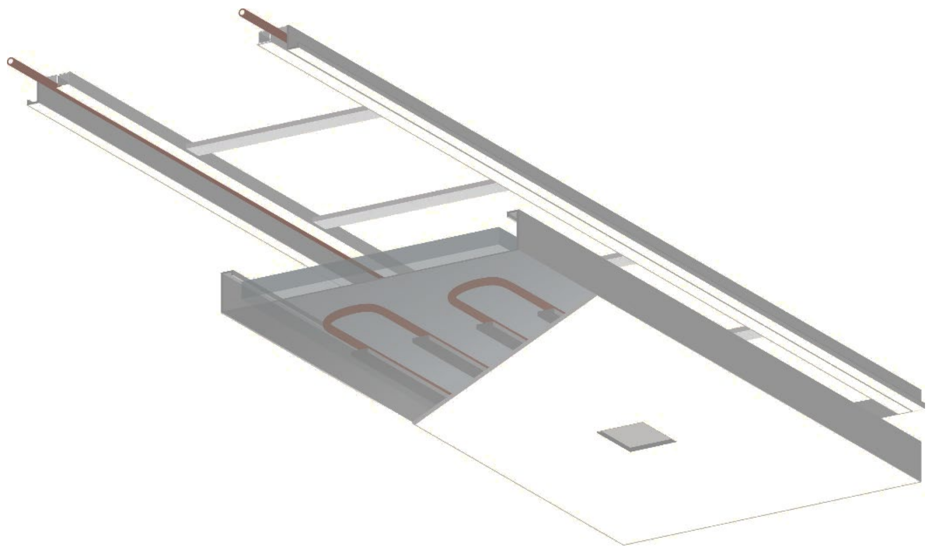
Overall, this results in the following improvements on the cost side:

- Lower investment costs due to smaller refrigeration unit and smaller or fewer cooling registers on the ceiling panels and/or smaller chilled sails.
- Lower running costs thanks to lower energy costs, most of which are at the night tariff.
- Higher flow temperature possible due to smaller loads which are dissipated during the day, leading to better COP of the refrigeration unit.

[1] Coefficient of performance

System: mass connection via water pipes

In the case of direct connection of the concrete ceiling via water pipes, the metal ceiling panels are mounted in a frame. This frame also has water pipes and is screwed directly onto the concrete. Energy can then be absorbed from the concrete. This principle ensures that the concrete cools down massively overnight and leads to high capacity via the mass connection.



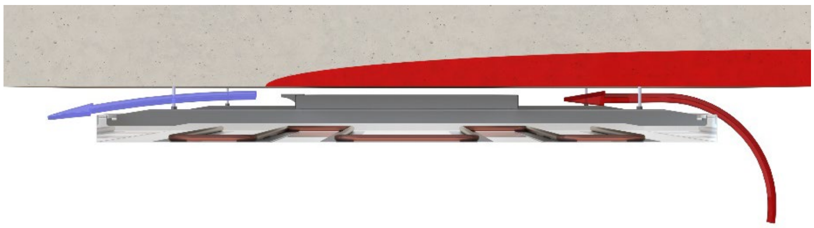
However, these systems have an adverse effect on the cooling capacity of the ceiling panel during the day. Chilled sails can generally achieve a high cooling capacity, as their upper surface is in contact with the room air. This energy exchange is prevented, however, if the radiant ceiling panel is mounted in an enclosed frame.

Furthermore, the water flows in series into the pipe of the frame and the ceiling panel. As a result, there is a risk of the room overheating in winter: as long as there are no people in the room and there are no solar loads (during the night), heating takes place in series and the concrete is also heated. Although the heat output is reduced by the radiant ceiling controller, if people then enter the room or the sun begins to shine intensively on the façade, the heated-up concrete ceiling cannot absorb any more energy. However, since most buildings are operated with reduced room temperature at night, this effect rarely occurs.

System: mass connection via air and radiation

Mass connection via air and radiation makes use of two different effects. On the one hand, the supply air flow (which is a hygiene requirement) is guided over the radiant ceiling during the day, drawing warm room air behind it along the concrete. The resulting quite high speed of the air on the concrete leads to a higher heat transmission coefficient and therefore a high injection of energy into the concrete during the day. With conventional systems, the supply air is switched off at night. The cooling of the radiant ceiling then dissipates the energy accumulated in the concrete during the day via convection and radiation.
In order for this effect to function fully, no mineral wool mats must be used for sound absorption on the ceiling panel.

Situation during the day:



Situation at night:

The main benefit of this is the greatly increased cooling capacity of the radiant ceiling during the day, because the warm room air is drawn over the ceiling's cooling registers in addition to the concrete. This leads to an additional increase in energy efficiency and reduced investment costs for activation.

There are various different systems of this type on the market. The key aspects to look out for are evenly distributed air flow over the whole ceiling surface and air movement from the (warm) façade towards the corridor zone. Systems that blow air out towards the façade have a significantly reduced effect, because the hottest room air is not reliably guided onto the upper surface of the ceiling panels. In addition, supply air that is blown against the natural room air circulation can lead to draughts.

System: mass connection via radiation

Systems are available in which mass connection is achieved via radiation alone, without the use of an auxiliary supply air system.

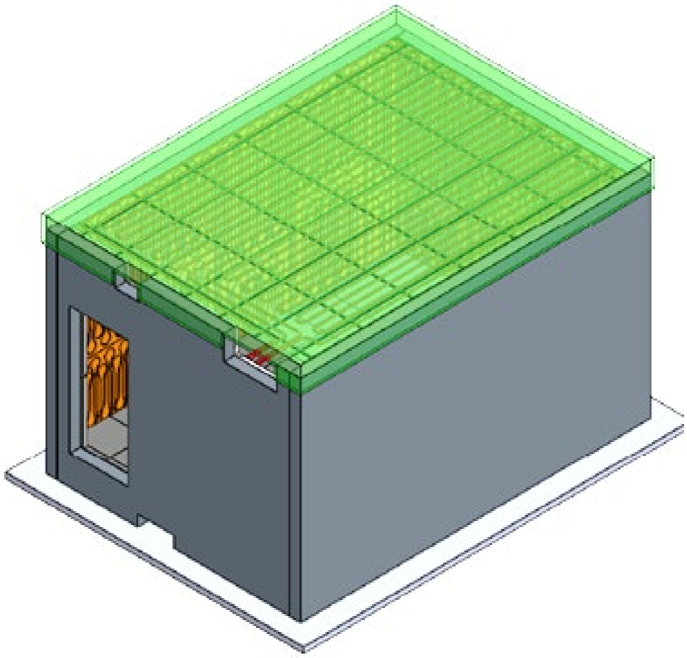
While the radiation exchange can cool the concrete ceiling at night, there is no increased injection of energy into the concrete ceiling during the day. The mass connection effect is therefore limited overall.

It is important to bear in mind that mineral wool mats, which are often used as a measure for improving the room's acoustics and are installed on the upper surface of the ceiling panels, significantly reduce the capacity of the radiant ceiling to radiate energy towards the concrete. However, these acoustic mats are essential for good room acoustics.

System: concrete core tempering

Although the concrete core tempering (CCT) system differs from that of a radiant ceiling, it should be explored in this context for the sake of completeness.

With concrete core tempering (also known as concrete core activation or thermally activated building systems), plastic or plastic composite pipes are embedded in the concrete ceiling during its construction. The contact between these water pipes and the concrete is therefore very good and the heat is directly drawn out from the concrete.



Although concrete core activation effectively prevents overheating of the building, it nonetheless places high demands on the control technology. As well as a much lower cooling and heating capacity compared to suspended radiant ceilings, the response speed of a CCT ceiling to sudden changes in load is very slow, because the energy must first pass through the entire mass of the concrete.

Furthermore, buildings with concrete core activation offer no potential solutions for the positioning of fixtures (such as lights, sprinklers, etc.). In addition, chilled sails frequently need to be fitted to a large proportion of the concrete ceiling in order to improve the room acoustics.

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Summary

The following table aims to provide an overview of the various systems on the market. However, it should be noted that these systems are subdivided into a wide variety of different solutions, which vary greatly in terms of their benefits and cost.

Concrete connection system	Targeted concrete mass connection	Conventional concrete mass connection	Radiation	Concrete core tempering (CCT)
Day-night energy transfer	++	+	-	++
Cooling capacity of the radiant ceiling	++	+	+	-
Possibility of fixtures	+	++	++	-
Integral supply air	++	+(+)	-	--
Acoustic solution	+(+)	+(+)	+	--

Key to symbols:

++ very good
+ good
- poor
-- very poor

Conclusion

A precise evaluation of the different systems on the market is worthwhile. Effective connection of the concrete ceiling to a radiant ceiling requires a great deal of experience and planning. Consideration must also be given to the aesthetics and the installed height of the system.

Particularly with regard to high energy efficiency requirements and rising energy costs, systems which actively include the building mass in the climate control concept pay off.

Measurement of radiant ceilings with mass connection in climate laboratories or directly "in the field", i.e. in real buildings, is an essential requirement which an experienced radiant ceiling provider should be able to fulfil.

Any questions? Please contact us. The specialists at Barcol-Air are happy to help.

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