Knowledge Guide

Thermally Activated Building Systems

Ecophon SAINT-GOBAIN

A SOUND EFFECT ON PEOPLE

1. Thermally activated building systems (TABS)

Modern buildings require effective cooling systems. One solution for lowering the temperature is to cool the slab, allowing the room to be cooled by the ceiling – in other words using thermally activated building systems (TABS). One advantage of this solution is that the slab can store the cold air that is available during the night, another is that the cooling takes place with hardly any air movement, which can otherwise cause draughts and discomfort.

A challenge arises when this system is combined with a requirement for good acoustics. The traditional solution – fully covering, Absorption Class A acoustic ceiling – does not work, as the cooling effect from the concrete is shielded by the ceiling. One solution is to use free-hanging units, which improve the acoustics in addition to allowing effective cooling.

Ecophon has performed tests based on the European standard EN 14240:2004 in order to evaluate how the cooling effect is influenced by free-hanging units. The results of these tests have been combined with similar test reports from other parties in a general graph. The results indicate that the cooling is to a large extent the result of natural convection and that it is important not to impede the air movement around the ceiling units.

Ecophon consequently recommends free-hanging acoustic units in combination with wall absorbers and absorbing screens in order to achieve the optimum sound climate with TABS. Ecophon Akusto is recommended to be installed where possible.

Glossary

TABS	Thermally activated building systems. The system can be active or passive.
Radiation	Heat transfer by electromagnetic heat radiation due to different temperature between elements (bodies and slab).
Convection	Heat transfer that depends on a flow of air. The air flow occurs between bodies with different temperatures.
Cooling efficiency	The remaining cooling effect from the cooling system in percent after acoustic treatment.
Ceiling coverage ratio	Area of free-hanging units divided by the total ceiling area.

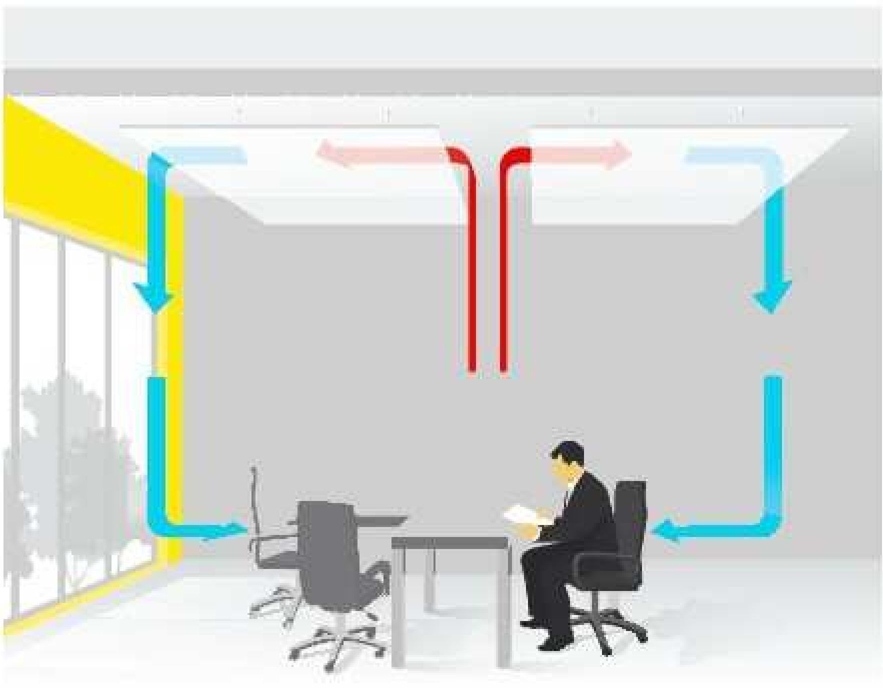
2. Heat transfer modes: convection and radiation

The two main principles for providing a room with comfort cooling are to supply the room with cooled air or to reduce the temperature of one or some of the room's surrounding surfaces, e.g. ceiling and walls. In the former case, the cooling is carried out by **convection** and, in the latter, by **radiation** exchange with the room's warmer surfaces in addition to convection.

Convection – definition

Convection is the movement of air caused by temperature differences in a room. It results from differences in the density of air at different temperatures. Air heated by the presence of a person or a computer, sunlight hitting the floor, etc., will rise and will be replaced by cool air, leading to an upward movement. Further away in the room, a corresponding downward air movement will take place. This type of convection is called natural, but it is possible to accelerate or increase convection with help of fans (forced convection).

As it rises in temperature, air becomes less dense and therefore lighter. As it travels upwards, the warm air will push away the air volume above it. The colder air is pushed aside, before it sinks, while the warm air climbs until it reaches the soffit (i.e. the concrete slab). The factors influencing the speed at which air will cool down are the soffit temperature, the air velocity at the interface with the soffit, the texture of the soffit surface (rough v smooth). The quicker the air cools down in contact with the soffit, the more dense it becomes, so it sinks again towards the floor. For a given amount of heat that initiates this convection movement, the presence of a cool soffit will accelerate and emphasize the convection flow.



Influence of horizontal absorbers on convection

The presence of free-hanging elements influences the convection transfer, as there will be an interference with the air flow. This interference will depend on:

- the overall room situation (orientation, sunlight exposure, etc.)

- the temperature conditions close to the floor
- the soffit temperature
- the size of the acoustic elements
- the distance between these elements
- the relative position of these elements

Depending on the combination of these different parameters, interference is not necessarily negative to convection. Three aspects are particularly important:

1. air should be able to rise between the free-hanging elements (generally at the centre of the room, assuming that is where people are located)
2. air should be able to move horizontally in the void between the soffit and the free-hanging elements
3. air needs to be able to descend easily between the free-hanging elements back into the room (generally at the periphery of the room)

If these conditions are fulfilled, then convection is compatible with the presence of free-hanging acoustic elements, taking into account some interference.

Radiation

Radiation relates to the heat transfer between the surfaces of two different bodies at different temperatures. Heat is transferred by electromagnetic waves from warmer objects to cooler ones. Bodies and surfaces exchanging heat energy through radiation need not be in contact but simply in sight of one another since the transfer occurs by thermal radiation.

Radiation is an efficient way to convey energy, and large amounts of energy can be transported even through limited surface areas.

Radiative heat (cooling) exchange between two objects depends on their respective temperatures, the nature of the surface of the object (its capacity to emit heat, known as emissivity) as well as the shape and dimensions of the object.

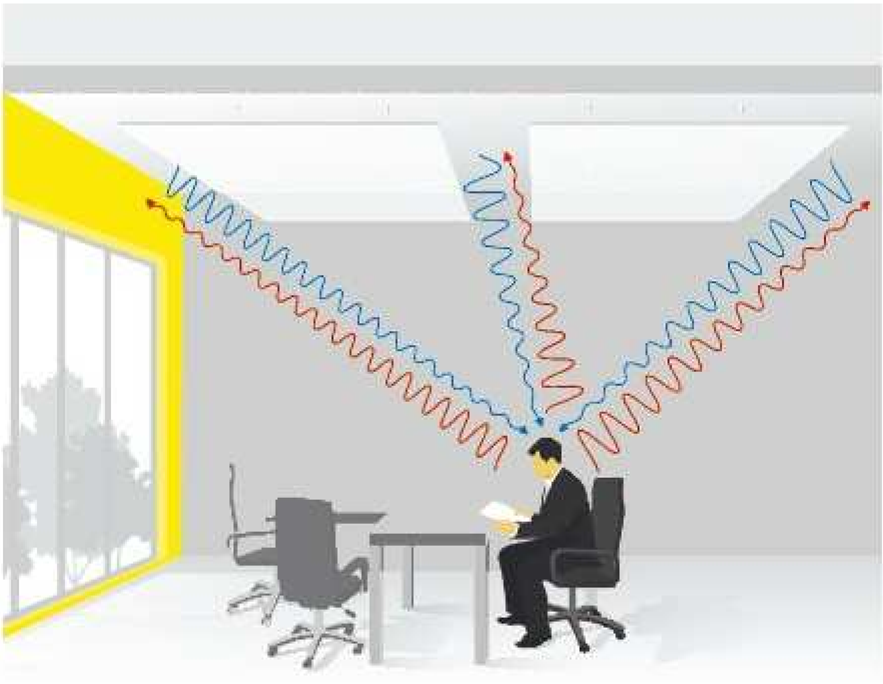
Emissivity: The emissivity of a material (usually written ε or e) is defined as the relative ability of its surface at a given temperature to emit energy by radiation. It is the ratio of energy radiated by a particular material to the amount of energy radiated by a black body at the same surface temperature. A true black body has in theory an emissivity $\varepsilon = 1$. A real object has an emissivity $\varepsilon < 1$. Since it is a ratio, emissivity is a dimensionless quantity, always between 0 and 1. In general, non-metals (especially non-transparent ones) have high emissivities (>0.8), whereas the emissivities of metals vary depending on the type of metal and its surface condition (matt or polished).

Influence of free-hanging elements on radiation

View factor: *In radiative heat transfer, a view factor is the proportion of the radiation which leaves surface A that strikes surface B.*

When free-hanging acoustic elements are suspended in a room, every point on the soffit can be grouped into one of the following categories:

1. Points that can be seen from any position in the room
2. Points that can be seen from some positions in the room
3. Points that cannot be seen from any position in the room



3. Active and passive systems

In order to lower the temperature of the soffit, several systems can be used, either passive or active.

- A passive system is when the building's concrete slab is allowed to cool down during the night (hence the term "overnight ventilation") when the outdoor temperature falls. Cooling is often achieved by leaving windows open sufficiently for cold air to flow in between two facades of the building. It is applicable in climates where the night temperature is much lower than day temperature. Overnight ventilation is also used to renew the air inside the building.

This principle is based on the large volume and mass of the concrete having a high heat capacity and thus levelling out temperature variations occurring throughout the day and night. The major disadvantage is that passive systems are difficult to regulate.

- Active systems, also called concrete core activation. This uses a coolant (generally water) which is sent through a network of pipes cast into the concrete. This technique can maintain the slab at a low temperature in a controlled way, and is less dependent on the climate than passive cooling, specifically when it comes to night air temperature.

<table>
<tr><td>Passive system during night</td><td>Passive system during day</td></tr>
<tr><td colspan="2">In large, modern buildings, active systems are frequently used. A system of pipes or tubing transports cold water that cools the ceiling area.</td></tr>
<tr><td colspan="2">
Active system</td></tr>
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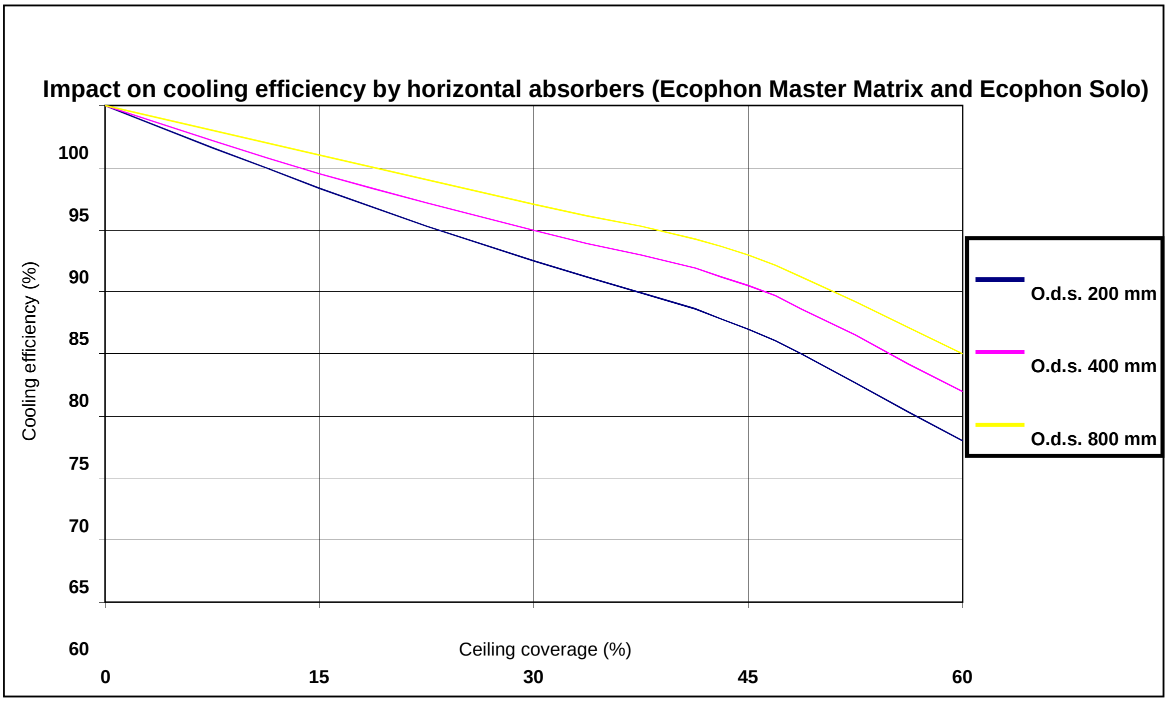
5. Laboratory measurements on horizontal and vertical absorbers

For several years Ecophon has gathered information on installation techniques for TABS alongside our own measurements and external technical reports. A common finding from both laboratory and field tests is that the loss in cooling efficiency is low in relation to the degree of ceiling coverage. This occurs because the natural convection part of the heat transfer increases and compensates for the loss of radiative heat transfer when free-hanging units are installed.

5a. Overall impact of free-hanging absorbers on cooling output

The values shown are from measurements without ventilation in the room. In real situations the cooling efficiency will be higher due to air movements caused by ventilation and activity within the room.



The diagram is valid for all types of Ecophon horizontal absorbers of 40 mm thickness, such as Ecophon Master™ Matrix and Ecophon Solo™, when the minimum distance between the absorbers is 200 mm and the distance between the absorbers and the wall is greater than 200 mm. The cooling efficiency is independent of the size and shape of individual absorbers. It is recommended that absorbers are distributed evenly within the room. It is possible to use this diagram when either an active or passive cooling system is used.

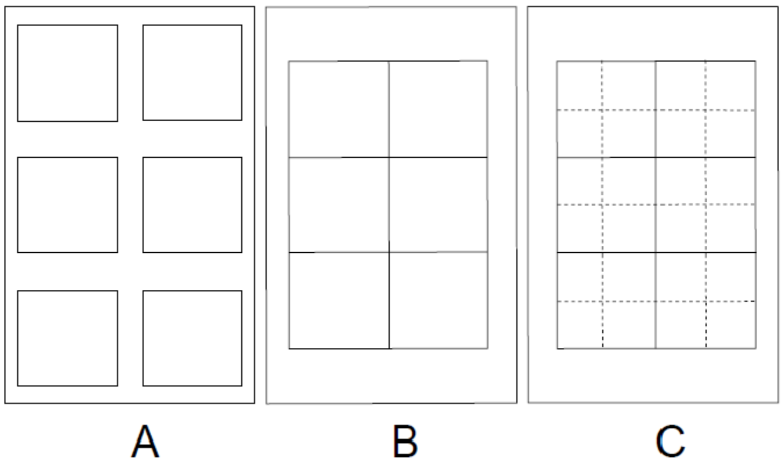
If several tiles are installed on different levels, the average distance between the absorber and concrete should be used. If a system has been installed with overlapping panels there has to be a column gap of at least 200 mm to get an accurate result with regard to radiation and convection.

5b. Further investigations on free-hanging absorbers' disposition and reverse-side coating

Laboratory measurements were performed at Peutz, in the Netherlands. They address the influence of clustering of free-hanging units on cooling output of an activated soffit.
By applying free-hanging units, the cooling capacity delivered by a thermally activated soffit is reduced, depending on the coverage ratio of the free-hanging units.
The laboratory measurements were carried out with 6 glass wool free-hanging panels (1200 x 1200 mm), corresponding to an effective coverage ratio of 60 per cent. The situation with the 6 panels evenly distributed over the ceiling surface is taken as the reference situation for the cooling output of the soffit.

- If the 6 panels are clustered without any space between each other, the cooling output delivery is reduced by approximately 15 per cent. The reference situation was also compared with the same disposition of panels, but with a darker reverse side (the reverse side is the upper side of the panel, facing the concrete soffit). The reverse side was coated with a non-woven glass fibre facing, whereas in the reference situation, it was painted white. The difference between the two configurations was negligible, confirming the theory of emissivity of non-glossy, non-metal surfaces.

Finally, a comparative measurement was made to evaluate the influence of a metallic grid on convection around the panels. The grid consisted of approximately 50-mm-high T-shaped profiles.



For the same coverage ratio of 60 per cent, four different configurations of horizontal absorbers were tested. The panels were mounted with an o.d.s. (overall depth of system) of 300 mm. Measurements were performed with different ceiling configurations. The following configurations were tested:

− Panels evenly distributed with painted reverse side ('A');
− Panels evenly distributed with non-painted reverse side ('A');
− Panels clustered with no space in between, non-painted reverse side ('B');
− Panels clustered with metallic T-profiles on top, with non-painted reverse side ('C').

5c. Influence of vertical absorbers (Ecophon Solo™ Baffle)

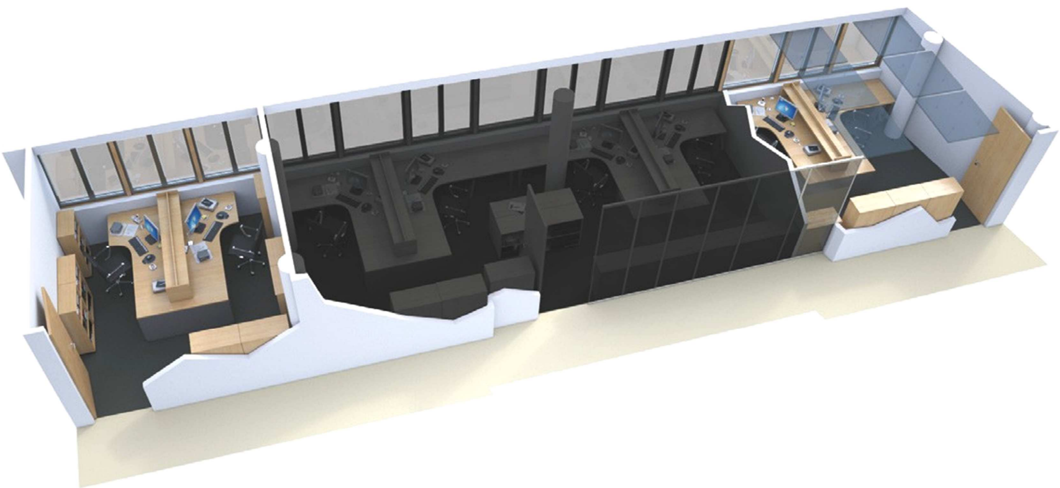
Ecophon has done two measurements on baffles according to EN 14240:2004. The baffles were installed in rows with two different spaces between the rows. The baffles were installed on the soffit not on hangers.

Product	**Degree of coverage**	**O.d.s.**	**Cooling efficiency**
16 x 3 pcs Solo Baffle 1200 x 300	200 mm space between baffles	Direct installation	84%
9 x 3 pcs Solo Baffle 1200 x 300	400 mm space between baffles	Direct installation	88%

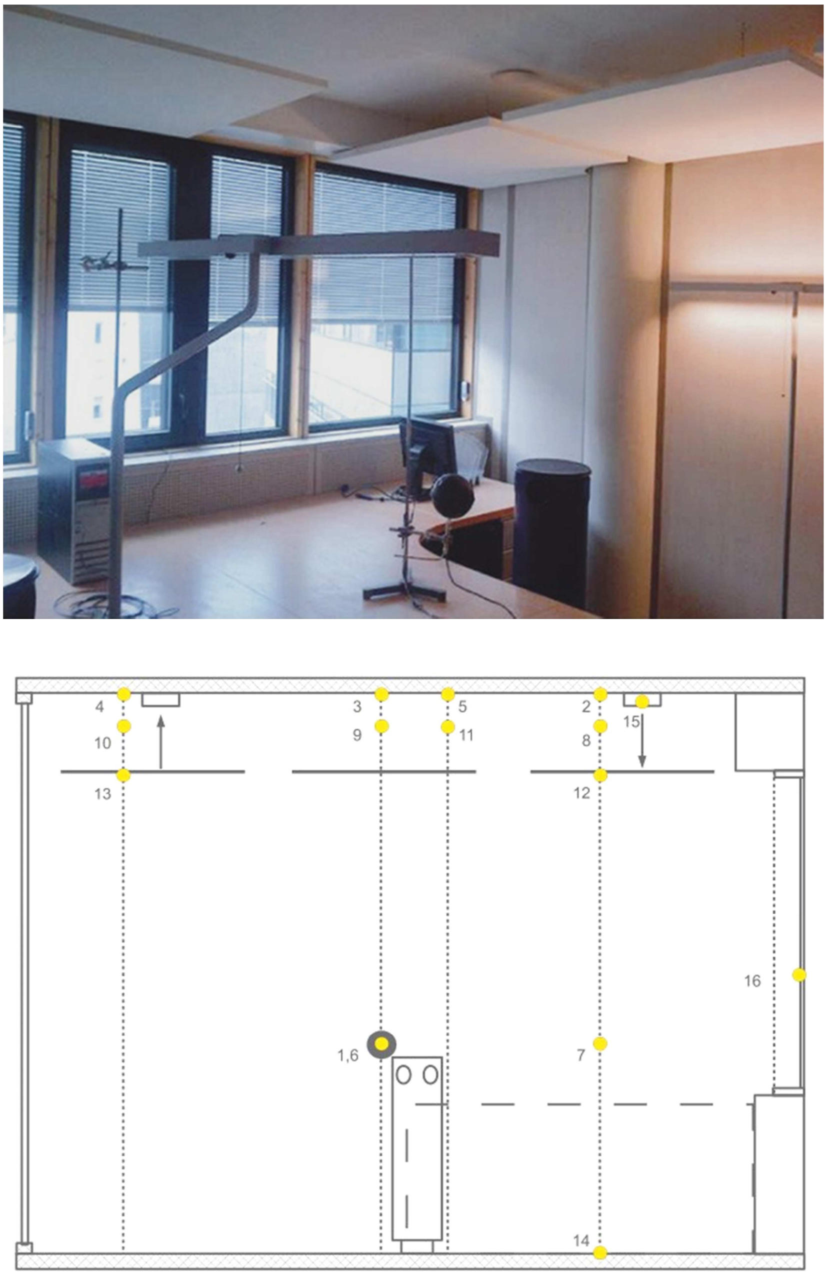
6. Field measurements on horizontal absorbers

A major field study was carried out in 2012 to compare temperature as well as room acoustics in two cell offices of the same size in the WOOPA building complex in Vaulx-en-Velin on the outskirts of Lyon in the south of France. The study is the result of a broad collaboration with, among others, Saint-Gobain Research, Ecophon and consulting experts in acoustic and thermal measurements.

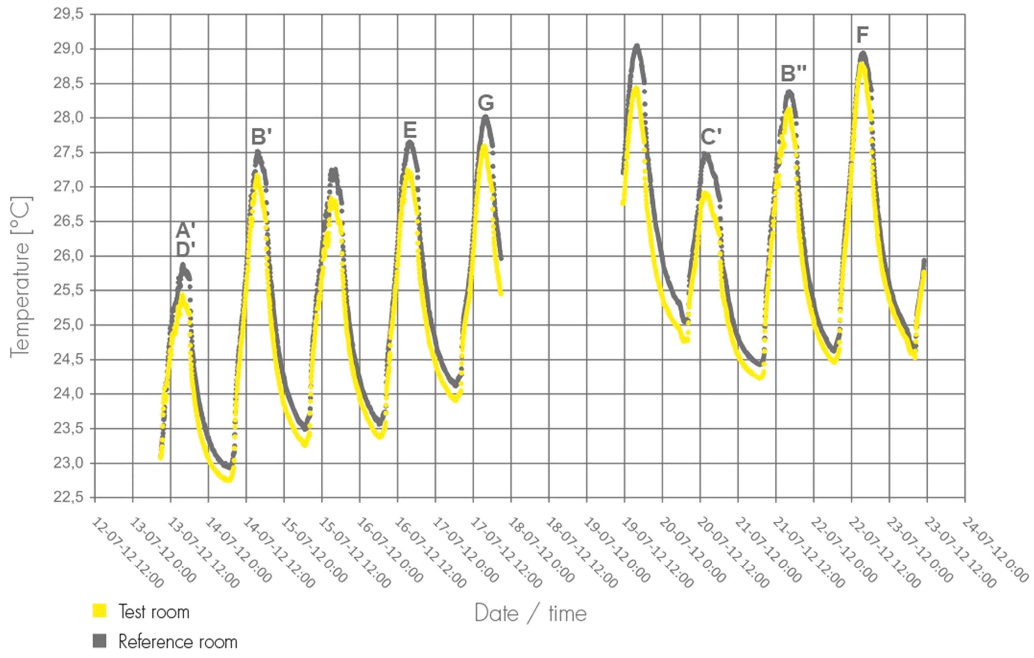
Project	WOOPA office building in Lyon, France
Type of test	in situ
Goal	To determine the influence of acoustic measures on the operative room temperature
Presentation of results	Difference between the operative temperature in the reference room and the test room
Convective support	Heating convectors, supply and exhaust air on the room ceiling
Measured value	Operative room temperature
Measurement period	Summer (June to August)
Systems used	Ecophon Solo™ Rectangle / Square



Reference room (left) and test room (right).

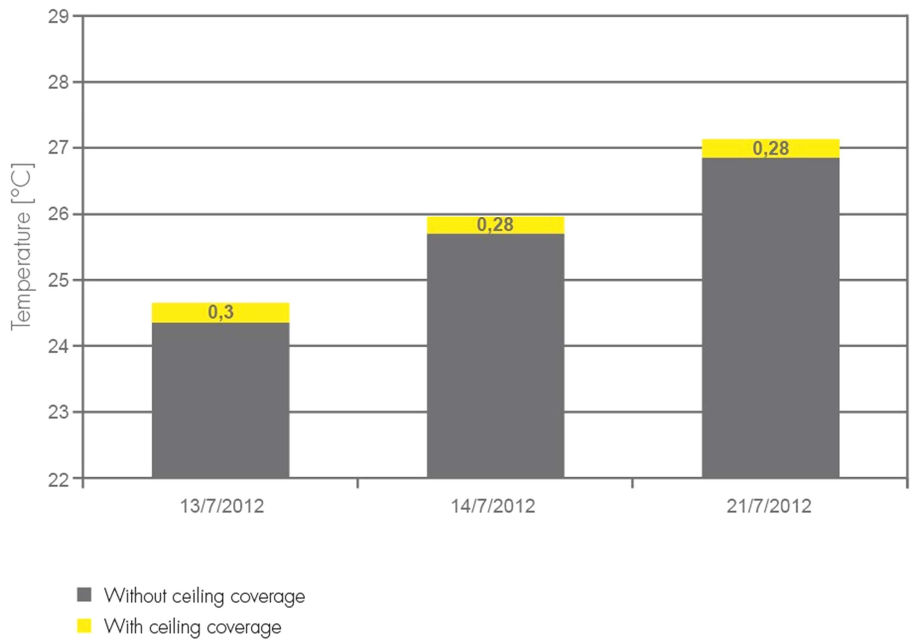


Test set-up.



Thermal measurements with acoustic ceiling panel (coverage 50%).

The results are summarised as follows:



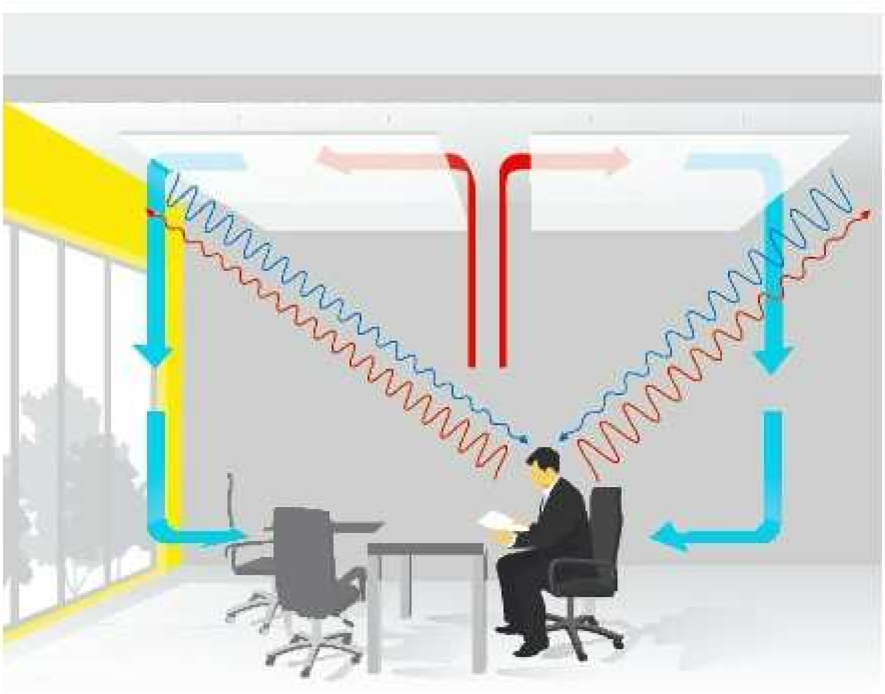
Calculation of the average operative temperature with and without horizontal absorbers in test room.

Degree of ceiling coverage	50% with ceiling panels
Acoustic comfort	Reverberation time 0.4s acc to ISO3382-1
Result	Difference of 0.3°C

**) The result is an estimation based on comparison of operative temperature between reference room and test room, and the variation of these differences on comparable days, as coverage changes in the test room. This is a field study result, and thus cannot be guaranteed for a different room type with a different set of conditions.*

6. Recommendations

It is advantageous to use solutions that allow a flow of air between the sound absorber and the concrete surface. In an actual installation, there is also considerably more air movement due to ventilation, open windows and activity in the premises than shown in test results. This air movement contributes further to reducing the effect of the free-hanging units on the cooling system. Convection cooling balances radiative cooling.



In real conditions, cooling occurs both by radiation and convection.

The basic principle for achieving good room acoustics is to introduce a sufficient amount of absorption into the room. To start with, the cumulative surface of the free-hanging absorbers should be equal to 60 per cent of the floor area. This is necessary, but not sufficient, due to the comparatively poor performance of free-hanging absorbers at low frequencies (from octave band 250 Hz and below). With regard to TABS buildings, this means that the horizontal absorbers are complemented with wall absorbers (such as Ecophon Akusto™ Wall) where possible, and those parts of the ceiling that have no cooling function are used for sound absorption. For example, visible ventilation pipes can be covered using Ecophon Focus™ Fixiform.

Ecophon Master™ Matrix, Ecophon Akusto™ Wall and Ecophon Focus™ Fixiform

Sound absorption should be installed, as far as possible, on fixed interior structures in order to ensure a long-term, satisfactory sound environment. However, flexible complementary absorption can be added using free-standing absorbing screens (such as Ecophon Akusto™ Screen).

In short:

- Tests by Ecophon show that covering the equivalent of 60 per cent of the floor area with absorbers on the soffit is an ideal solution for TABS buildings, both thermally and acoustically.

- To create the best combination of thermal and acoustic performance Ecophon recommends an even spacing of absorbers across the ceiling. Every unit should have at least 0.2-metre gaps on two opposite sides. The only exception is if you are using rows of vertical absorbers (baffles). Then the distance between the rows should be kept at 0.2 metres.

- In order to maintain the desired cooling effect, Ecophon recommends that the distance between the concrete and the free-hanging ceiling units is at least 0.2 metres. And according to our lab studies, both the thermal and acoustic performance will improve if you can increase this distance beyond 0.2 metres.

- When you combine 60 per cent coverage by ceiling units with wall absorbers, Ecophon recommends that the wall absorbers should cover walls to the equivalent of 20 per cent of the floor area. In an office where most people sit at desks, the wall panels should be centred at a height of 1.2 metres. In offices where most people stand, they should be centred at 1.6 metres.

All the tests and recommendations are based on Ecophon systems, with very high sound absorption qualities. These qualities are described as either equivalent absorption area (Aeq) or absorption factor (α) in our system specifications, which you can find on our website, www.ecophon.com. The results and recommendations presented here cannot therefore automatically be applied to other products, with lower Aeq or α.

Appendix

Compatibility of concrete core activation building and suspension of free-hanging elements.

In buildings with thermal activation of the slab, the presence of pipes close to the surface of the concrete might interfere with the soffit fixing for the suspension of acoustic elements. Drilling a hole could lead to the perforation of the pipes and thereby to leakage.

There are several ways to handle this conflict:

- Plan thoroughly to separate the areas where piping is integrated into the soffit from the areas in which elements are suspended. The distance between suspension zones depends on the type of free-hanging acoustic element (Ecophon Master^{TM} Matrix or Ecophon Solo^{TM}), the size of the elements or clusters and their layout or disposition throughout the room.
- Specify soffit fixing with a limited penetration in the concrete. One example is Flush anchor HKD M6x25 from Hilti. It is a drop-in anchor fixed by expansion using a bespoke setting tool. The anchor penetrates 25 mm into the concrete.
- Specify soffit fixing with surface adhesion such as glued fixing, mortar fixing and the like.

7. References:

Testing of acoustic ceiling boards influence on cooling capacity according to EN 14240:2004, SP - Technical Research Institute of Sweden, Borås, 2008

Weitzmann, Peter ; Pittarello, E. ; Olesen, Bjarne W. *The cooling capacity of the thermo active building system combined with acoustic ceiling*, Nordic Symposium on Building Physics, DTU, Kongens Lyngby, 2008

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Chigot, Pierre. *Office buildings and natural cooling: room acoustic demands and influence of acoustic treatment on thermal performance*. Proceedings of Inter-Noise, 39th International Congress and Exposition on Noise Control Engineering. 13–16 June 2010. Lisbon, Portugal.

Kreider, Jan F. Curtiss, Peter S., Rabl, Ari, *Heating and Cooling of Buildings: Design for Efficiency*, Revised Second Edition, CRC Press, Boca Raton, 2010, 843 p

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Ecophon ceiling panels in relation to Thermally Activated Building Systems (TABS) - Climatic chamber test, Peutz Report number DB 2805-2E-RA d.d. June 10, Mook, 2013

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Ecophon dates back to 1958, when the first sound absorbers from glass wool were produced in Sweden to improve the acoustic working environment. Today the company is a global supplier of acoustic systems that contribute to good room acoustics and a healthy indoor environment with the focus on offices, education, health care and industrial manufacturing premises. Ecophon is part of the Saint-Gobain Group and has sales units and distributors in many countries.

Ecophon's efforts are guided by a vision of attaining global leadership in room acoustic comfort through sound-absorbing systems, enhancing end-user performance and wellbeing. Ecophon maintains an ongoing dialogue with government agencies, working environment organisations and research institutes, and is involved in formulating national standards in the field of room acoustics where Ecophon contributes to a better working environment wherever people work and communicate.

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