The second of two articles on BATISO type buildings describes the role of displacement ventilation in achieving a high degree of human comfort.

Displacement Ventilation

by Geoff McDonell, P.Eng.

Last month, we saw how the Swiss "building physics" approach has led to the development of the BATISO building concept (an acronym for Batiment Isotherm—constant temperature building). The BATISO building system uses plastic tubing cast into the concrete structure of the building. Warm and cool water is pumped through the tubing to control the concrete slab temperature to create radiant cooling and heating as required. With the building's temperature control system satisfied by a radiant heating/ cooling system, the building air system only needs to provide treated, filtered outdoor air for healthy conditions and for building make-up air.

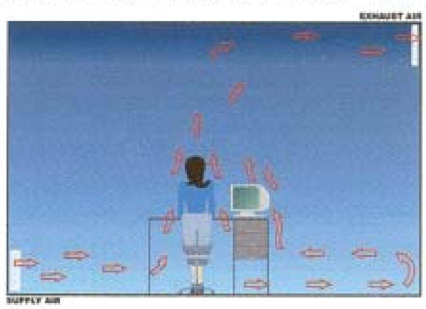
As a result, the building air system can become only 20% of the size one normally expects for an "all-air" type temperature control system. With the entire air distribution infrastructure becoming smaller, less mechanical and plenum space is required. This can assist in reducing floor-to-floor heights, allowing further economies to be made to the capital cost of the building. The effective distribution of the ventilation air can be accomplished in a number of traditional ways, via overhead ductwork or through raised floor plenums.

Displacement Ventilation

The European, and especially German, building codes are such that interior air movement velocities are defined and mandated, so air distribution is a very highly engineered aspect of the mechanical systems. Displacement ventilation systems are commonly used in order to keep air velocities in occupied spaces to less than 50 feet per minute—fpm (0.25 metres per second—m/s). Raised floor systems are generally used, as well as perimeter baseboard style air diffusers for effective room air diffusion and ventilation at low velocities. Most displacement air distribution systems are designed for a maximum outlet air velocity of 40 fpm (0.20 m/s) at a minimum supply air temperature of 17°C (63°F). While some supplemental cooling capacity can be provided by a displacement ventilation system, it is normally not considered if the primary cooling is being performed by a hydronic radiant cooling system.

Positive displacement air supply systems rely on low velocity air being distributed at low level and allowing stratified warm air to be returned or exhausted at high level. It is intended to work with "medium temperature" air at not less than 17°C to a nominal maximum of 22°C. The principle is to reduce the vertical gradient of the temperature difference of the supply air temperature relative to room air temperature, as well as to reduce the energy required to cool the supply air down to the 12°C temperatures normally used for all air systems.

The best applications for displacement ventilation systems are: areas with high ceilings where routing for low level air supply is available; spaces in which cooling loads have been minimized, so heating and cooling can be handled using hydronic radiant systems and the air system is not the primary source of heating or cooling; theatres or auditoriums where there is an opportunity to supply air at a low level in the seating area and allow stratification to high ceilings (an example where large ventilation air quantities are required due to the high population load, but ultra quiet air supply is also needed). For example, technology has been developed for the Reichstag Building in Berlin where perforated raised floor panels using a porous carpet are used to create supply air up through the carpet.



Above: displacement ventilation pattern diagram.

The maximum air velocity is around three to five fpm, which is not high enough to lift dust or dirt out of the carpet, and the carpet actually acts as an air filter to keep contaminants from the floor plenum from being blown up into the occupied space (a common problem in most raised floor air distribution systems using the higher velocity bucket type individual floor diffusers without terminal filters in them). Normal housekeeping will remove the trapped dust and keep this "final filter" clean.

Based on laboratory tests, the average human body, whether sitting or standing, can generate approximately 58 cubic feet per minute—cfm (100 cubic metres per hour—m^3/h)—of air movement due to the buoyant/ convective effect of the body temperature relative to 70°F ambient air. Cool air at low level is drawn up and past a heat source (e.g. human body) to return/exhaust grilles at or near the ceiling level of the room, creating an ideal air movement path for superior indoor air quality.

In one test lab situation, a room was simulated based on a chilled ceiling system and floor plenum air distribution system, with a space-cooling load of approximately 80 watts per square metre (w/m^2). The ceiling surface temperature was maintained at 17°C by capillary mats in suspended ceiling panels (see *CA* March 2003), the supply air temperature was approximately 20°C, and the room air temperature remained at 20-21°C in the occupied zone throughout the test. Cold smoke sticks were used to track air movement, and using passive displacement air through the floor, it was clear that air movement resulted in clean primary air being attracted to and rising up at the heat sources, effectively carrying away air contaminants and body heat to upper levels of the room.

Track Record

Many Swiss BATISO buildings have been operating successfully for 15 years and their performance has been tracked and recorded. Typically, a thermo-active slab office building uses 70% less energy than the best conventional all-air HVAC system (four-pipe fan-coils with high-efficiency mechanical plant), and the indoor comfort conditions are superior to other contemporary buildings. The other key fact is that the capital cost of these BATISO buildings is often equal to or less than a conventional building approach.

In North America, there are presently only two functional commercial radiant slab cooling systems that I know of: the ICT Building at the University of Calgary by Stantec Architecture Ltd./HOK Canada/Barry Johns Architecture Ltd. with Earth Tech as mechanical and electrical consultant (see *CA* January 2002); and Gleneagles Community Center, West Vancouver, B.C., by Patkau Architects with Earth Tech as mechanical and electrical consultant.

There are also a number of suspended radiant panel installations which provide heating primarily, with some systems designed to provide supplemental cooling, to augment the all-air main HVAC system, and to deal with the low performance building envelope.

Radiant Slab Building Costs

The key to a successful radiant slab building is control over the economics. Achieving a high performance building envelope is normally assumed to create premium cost for a building project, but the key is to provide equivalent savings in the rest of the building systems.

Based on direct construction cost records for radiant slab buildings, both in Europe and the two Canadian examples, the costs for a standard office building work out such that it can cost less to build a radiant slab building, yet it uses up to 70% less energy than conventional approaches.

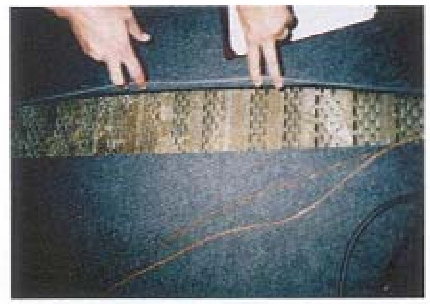
Using the United States Green Building Council LEED point system, the radiant slab HVAC system can contribute to a relatively easy LEED gold standard building, provided the other LEED components are incorporated for the rest of the project.

Building Component	Conventional Building	Radiant Slab Building
Glazing*	14.00 $/SF	19.00 $/SF
Mechanical System	22.00 $/SF	14.00 $/SF
Electrical System	16.00 $/SF	15.00 $/SF
Floor to Floor Height	12'-6"	11'-0"
Tenant Upgrade Costs	10.00 $/SF	7.00 $/SF
Energy Use	18 kwh/SF/year	10 kwh/SF/year

*Based on 50% glazing area/wall ratio.

The table above shows average costs—not location-specific—based on current quantity surveyor costing data and backed up by built and costed examples of radiant slab office buildings over the last three years. It is obvious that an integrated building design team can build a low energy, sustainable building for less cost than a conventional building approach.

In European low energy BATISO type buildings, the mechanical plant size is generally 40% of the size as compared to a standard building right next door. The premium cost of the high-performance building envelope can be easily offset by the savings in mechanical plant size, now that all the heating and cooling is done by a hydronic system rather than masses of air. The energy savings track record of BATISO type buildings dating back over 12 years indicates that energy savings of 70% less than conventional systems are common. An air system is still required to provide the outdoor air for ventilation, typically 20% of the air normally circulated by an all-air type system but, it only needs to be supplied at room temperature, so the fan power, and the heating and cooling requirements for moving and conditioning this air are much reduced. Such a system addresses all of the human comfort components: Radiation, Convection and Evaporation. ca



Top: a graphic example of passive displacement air flow across the floor in a test lab. Above: example of a "through the floor" air supply system as used in Germany.