CBE is developing design and specification guidelines for configuring and operating underfloor plenums as part of an intelligent approach to underfloor air distribution technology. This report summarizes results from the first phase of this project, where full-scale empirical testing carried out in April 1998 was used to investigate plenum configuration issues, including minimum plenum height, for which acceptable air flow performance can be achieved in a pressurized underfloor plenum. In an unoccupied, open plan test facility equipped with a raised access floor, air flow performance was measured in terms of the ability of the underfloor air supply plenum to uniformly distribute air to all floor grills within the test space for a given air supply volume and plenum configuration. This determination is a critical factor affecting the wider use of underfloor air distribution in both new and retrofit construction.
performance of pressurized, low-height, underfloor air supply plenums and identify practical limits for acceptable performance, including the following:
What is the minimum plenum height at which acceptable air flow performance can still be achieved?
What effect of obstructions (e.g., cables, ducts) have on air flow performance in low-height underfloor plenums?
What is the maximum floor area that can be adequately served using a single primary air inlet location to the plenum?

Test Facility

In April 1998, CBE researchers set up a full-scale underfloor air supply plenum test facility in a 40-foot by 80-foot (12-m by 24-m) unoccupied open-plan area with an 8-inch (205-mm) raised access floor providing 7 inches [180 mm] of clear space between the concrete slab and the underside of raised floor panels, in a large office building.

Air was supplied into the plenum at two points along one 40-ft edge by two centrifugal inline fans with one-hp variable speed motors, and up to 32 rectangular 4-inch by 14-inch (100-mm by 360-mm) floor grills, evenly distributed across the plenum, served as the air supply outlets from the plenum to the room.

Although the grill designs used do not represent typical floor diffusers found in office installations adjustable dampers were used to increase the flow resistance of the grills to a more representative value. The perimeter edges of the test area were sealed with a combination of plastic sheeting and duct tape. Three plenum heights were investigated (7-inch [180-mm], 3-inch [75-mm] and 2-inch [50-mm] clear space) under a range of air supply volumes, obstruction conditions, and other plenum configurations.
Test Conditions

Five separate week-long field experiments were conducted in the test facility between April and December 1998. Each test was performed under steady-state conditions and the following measurements were made: (1) supply volume into the plenum at the fan inlet duct, (2) static pressures relative to room pressures, measured with digital micro-manometer and pitot tube; and air velocities, measured with a hot wire anemometer, in the plenum, and (3) supply volume delivered to the room using a flow hood at each floor grill.

Height of clear space in plenum: 7 inches, 3 inches, 2 inches (180 mm, 75 mm, 50 mm)
Total supply volume into plenum: 0.5, 1.0, 1.5 cfm/ft² (2.5, 5.1, 7.6 L/(s.m²))
Obstructions placed across width:
- 7-inch plenum: 4-inch (100-mm) of plenum and 5.5-inch (140-mm) obstruction at 21 feet (6.4 m)
- 3-inch plenum: 1 and 2 two-inch (50-mm) obstructions at 21 feet (6.4 m) and 41 feet (12.5 m)
Flow resistance of floor grills: Low resistance (open dampers), High resistance (closed-down dampers)
Total number of floor grills: 16,32
Open panels (panels removed): Two panels removed near fan inlet in raised floor, two panels removed at far end of plenum
Change in direction of air flow at fan inlet: Full-height underfloor barriers in front of fan inlets

Instrumentation

All instrumentation was either new (flow measurement station) or calibrated prior to use [16]. The flow measurement stations mounted in the straight ducts upstream of the fans each measured the air flow volume to within 8 cfm (3.8 L/s) (manufacturer's specified accuracy), corresponding to an error of only 1% at the lowest flow rate tested (0.5 cfm/ft² [2.5 L/(s.m²)]). The micro-manometer agreed to within 6% of a high precision liquid manometer over the range of pressures measured in this study. The hot-wire anemometer had a manufacturer's specified accuracy of 3% of the reading ±20 fpm (0.1 m/s). The flow hood was calibrated twice: once in our laboratory and once by the manufacturer. The interpretation of the flow hood data is discussed further below.

Results
Floor grills were initially installed with their dampers largely open (low resistance), resulting in lower than normal plenum static pressures. It was decided to close down the dampers enough (high resistance) to produce an average plenum pressure at the highest air flow rate (1.5 cfm/ft² [7.6 L/(s.m²)]) that was representative of typical operating pressures (0.07-0.08 in. H₂O [17-20 Pa]) for pressurized underfloor air supply plenums using commercially available floor diffusers. Unless otherwise noted, all results presented below are for the grills in the more representative, higher resistance configuration.

Conclusions

Based on the findings, CBE recommends the following:
In specifying the height of an underfloor air supply plenum, CBE recommends that, on average, at least 3 inches of clear space for air flow be provided in an underfloor plenum in addition to the height required for other factors.

Solid obstructions, even with only 1.5 inches (38 mm) of clear space above them, may be located in plenum with a minimum 7 inches of clear space and have very little impact on the overall air flow performance.

If one or two floor panels are removed for service or repair work, the amount of air delivered to floor outlets in that same zone may be reduced by up to 50%. As overall zone distribution is unchanged, this is acceptable on a short term basis.

At the primary air inlet to an underfloor plenum, air may be delivered horizontally or vertically with little impact on the air flow performance in a plenum with at least 7 inches (180 mm) of clear space.

No significant degradation in performance was observed when the number of outlets was reduced by 50% in both 3-inch (75-mm) and 2-inch (50-mm) plenums at a nominal air flow rate of 1.0 cfm/ft (5.1 L/s).

Additional important considerations include the thermal performance, or variations in supply air temperature across the area of the plenum.
Key issues to be addressed include thermal storage in the concrete slab, heat transfer rate to the underfloor air supply, and air temperature variations across the plenum.

Future and On-going Work

In addition to the air flow performance findings of this report, thermal performance issues will play an important role in the optimal design and operation of underfloor air supply plenums. Future work on this CBE project will investigate the thermal performance of underfloor plenums through a combination of full-scale experiments and CFD (computational fluid dynamics) and other modeling methods. Key issues to be addressed will include the thermal storage in the concrete slab, the heat transfer rate to the underfloor air supply, and air temperature variations across the plenum. Whole-building energy simulations will also be performed to study the energy use implications of using underfloor air distribution.

On the commercial side, more products are needed that support the wider application of underfloor air distribution technology. In particular, low-height underfloor plenums, as discussed in this paper, will require the development of low-profile floor grills, supply modules, and other air distribution equipment.

Full Report

For the full version of the Summary report "How Low Can You Go?" Air Flow Performance Of Low-Height Underfloor Plenums
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