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FULL-SCALE MODELING, A USEFUL TOOL IN PLANNING

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ABSTRACT

Experiments for establishing advantages offered by full-scale modeling of workrooms have been conducted, to avoid design faults and to improve working environment quality. A physician's reception room was built in the laboratory in order to perform full-scale measurements. Thermal environment, behaviour of HVAC system, acoustical properties, lighting and material emissions have been investigated. Some new solutions for constructions have been found. With this experiment it has been ensured that it is possible to obtain desired quality in the planned building. Modelling has been found useful in cases where several similar rooms are built.

INTRODUCTION

Different kinds of problems often exist in new buildings. They may be caused by draft, temperature differences, capacity of heating and cooling systems, regulators in HVAC system, sound insulation, material emissions and lighting. When high quality is wanted, these factors should be investigated properly before building. By using full-scale modelling, most of these problems can be avoided. Full-scale modelling has also other benefits. For example, different furnishings and colours of materials can be studied. It is also much easier for the users of the planned building to take part in planning if they can actually see the solutions.

MATERIAL AND METHODS

Conditions in a building or a room can be evaluated by different factors. Limits or desired values can be determined using, for example, the references listed in Table 1.

To ensure that measurements are done in controlled environment, the room has to be built into a laboratory. The accuracy of regulators and probes of the air conditioning equipment have to be verified. Methods of measuring air flow rates in air ducts are given in ISO-standard 5221 [1]. Air temperature measurements and requirements for measuring equipment are found in ISO-standard 7726 [2]. Also measurements for conditions in the room have to be done according to corresponding standards. For example, requirements for air velocity measurements are given in ISO-standard 7726. Equipment for simulating heat loads and cold surfaces are also important.

Table 1. References for temperature, air velocity, temperature difference, assymmetry of thermal radiation, sound reduction, reverberation time, the rapid speech transmission index (RASTI) and material emissions.

factor	reference	limits or desired values
temperature	Scanvac [3]	summer: - highest value: 23 ... 26 °C * - optimal value: 22 °C - lowest value: 21 ... 18 °C * winter: - highest value: 23 ... 26 °C * - optimal value: 22 °C * - lowest value: 21 ... 18 °C *
temperature difference (0.1 - 1.1 m)	Scanvac	2.5 ... 3 °C *
draft	Scanvac	summer: 0.20 ... 0.40 m/s * winter: 0.10 ... 0.25 m/s *
asymmetry of thermal radiation	Scanvac	hot ceiling: 4 ... 6 °C * cold wall: 8 ... 12 °C *
sound reduction	Finnish building code C1 [4]	between reception rooms 48 dB between room and corridor 34 dB
reverberation time	Finnish building code C1	reception room: 0.6 s (250 - 2000 Hz) corridor: 1.3 s(500 - 4000 Hz)
RASTI	**	< 0.75
TVOC	Scanvac	0.2 ... 0.5 mg/m^3
Formaldehyde	Scanvac	0.05 ... 0.1 mg/m^3

* depending on quality class

** recommendation from Institute of Occupational Health, Finland

In this study, a simulated physician's reception room was built in the laboratory. The main object of the study was the capacity and behaviour of the air conditioning system, which was tested both under normal and extreme weather conditions (Table 2).

Table 2. Measurements were done in the following situations.

situation	simulated outdoor temperature (°C)	Internal loads (W)
1. cold morning	- 35	100
2. cold period	- 35	680
3. cold period	- 26	680
4. cold morning	- 20	100
5. cold period	- 5	680
6. cooling period	+ 22	680
7. cooling period	+ 22	980

The floor area of the reception room was 5.0 x 3.5 m² and the height was 2.6 m (Figure 1). Heating and cooling were integrated in air conditioning units which were mounted in the ceiling. There were two units in the room. The room was warmed up mainly by radiant heating from the lower surface of the unit and cooled down with convective flow from a heat-exchanger. The supply air was blown from the one end of the unit along the ceiling. The exhaust air was taken from the room through a grille. The cross section of the room is shown in Figure 1. The temperature in the room was controlled by a regulator, which was placed on a sidewall at the height of 1.7 m. Sunshine was simulated with heaters placed horizontally on the floor and the surface of the window was cooled down to simulate winter season conditions. Also the heat load from the physician and patient was simulated with heaters placed on their chairs.

It was examined how the unit can heat and cool the room and what kind of air velocities occurs in the room. Air velocity, air temperature and turbulence intensity (the ratio between the standard deviation of the air velocity and the mean air velocity) were measured at two cross sections (96 points) in the room with 24 hot wire omnidirectional transducers Fig. 2. Velocity vectors were measured in some tests with ultrasonic anemometer. Draft risk (predicted number of dissatisfied) [5] was calculated using formula

$$\textbf{Draft risk} = (3.143+0.369\ v\ Tu)\ (34-Ta)(v-0.05)^{0.622} \quad (1)$$

where **v** = mean air velocity (m/s)
Tu = turbulence intensity (%)
Ta = air temperature (°C)

Asymmetry of thermal radiation was also measured. Temperatures of supply and exhaust air, surface temperatures of heaters and windows and temperatures of heating and cooling liquids were monitored. The room had furnishings during the measurements.

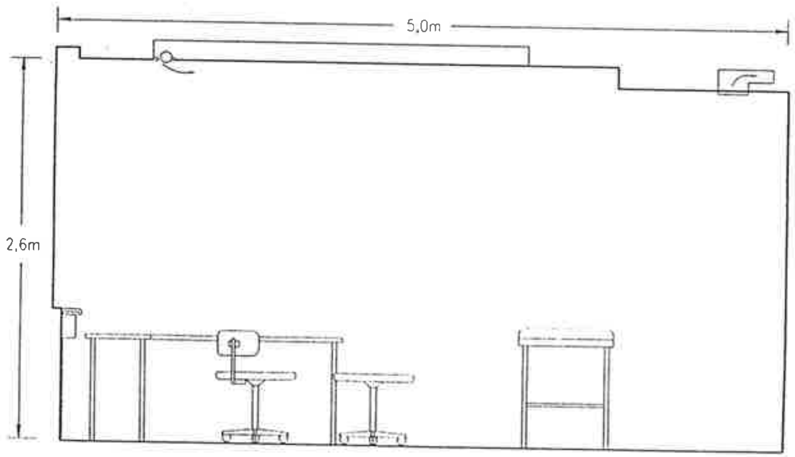

Fig. 1. The cross section of the room.

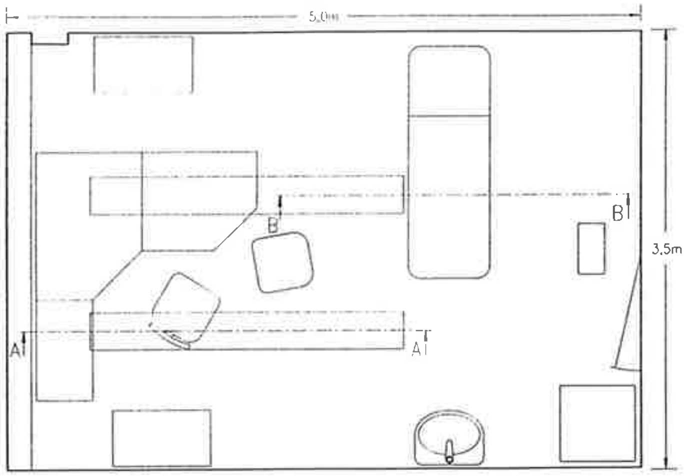

Fig. 2. The placement of the air conditioning units (screened areas) and the locations of the cross sections A-A and B-B in the room.

Material emissions were measured immediately after furnishing the room and the measurements were repeated two weeks later. For monitoring of volatile organic compounds (VOC), both activated carbon and XAD-resin were used for the sampling. The collected compounds were analyzed with GC-MS. For the determination of formaldehyde, chemosorption technique was used (sampling on diphenylhydrazinetreated glass-fiber filter in combination with HPLC).

The measurements included also acoustical parameters. Sound reduction between the reception room and other spaces was measured. Also RASTI values and reverberation time were measured.

Table 3. Measured factors.

Air conditioning and thermal environment	acoustic environment	material emissions
• air flow rates • temperatures of supply and exhaust air • flow rates and temperatures of cooling and heating liquids • air velocity, turbulence intensity and draft risk • air and surface temperatures • asymmetry of thermal radiation	• sound insulation • RASTI • reverberation time • A-sound pressure level	• amount of VOC's • amount of formaldehyde

RESULTS

Air velocities measured around physician's workstation and examination table are shown in Table 4. Measured air velocities (case 5) are shown in Figure 3, and the draft risk under the same conditions, in Figure 4.

Table 4. Measured mean air velocities in different situations.

situation	air velocity (m/s) side table	physician's workstation	floor / physician's workstation	floor / examination table	examination table
1. cold morning	0.2	0.15	0.1	0.05-0.1	0.1
2. cold period	0.2	0.15	0.1-0.15	0.05-0.1	0.05
3. cold period	0.2	0.05-0.1	0.1	0.05	0.1-0.15
4. cold morning	0.2	0.15	0.1-0.15	0.1	0.1
5. cold period	0.1	0.05-0.1	0.1	0.2	0.1
6. cooling period	0.1	0.1-0.15	0.1-0.15	0.25	0.1
7. cooling period	0.1	0.1-0.15	0.1-0.15	0.25	0.1

The vertical air temperature differences between head and ankle level were in all measured situations less than 1.5 °C. Also the radiant temperature asymmetries from cold windows (0.5 °C) and heaters (4.4 °C) were moderate. The HVAC system maintained a stable temperature in the room both during heating and cooling periods. Recommendation for placing the furniture was determined to prevent draft risk under extreme conditions. Also, optimal openings for the supply air device were examined. Some improvements were proposed to the sound insulation. For the acoustical environment, some new arrangements were made to achieve the desired results. The requirements were fulfilled after the improvements were made.

The initial material emission values were for total VOC 2.7 mg/m³ and for formaldehyde 0.058 mg/m³. Two weeks later the corresponding measured values were 0.199 and 0.035 mg/m³, respectively. During the first measurements, the air conditioning system was not operating, in order to measure the worst possible case. After the first measurements, air conditioning was turned on.

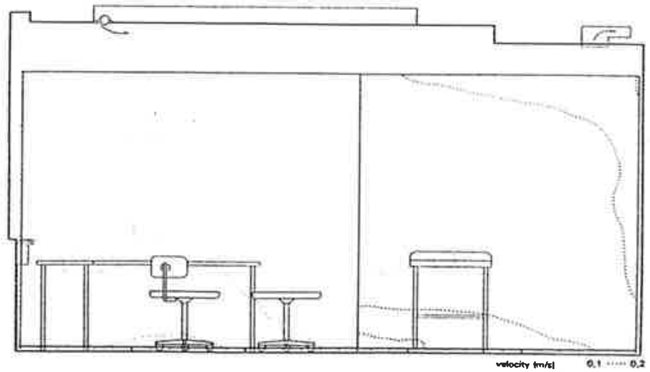

Fig 3. Measured air velocities (m/s) (outdoor air temperature -5 °C).

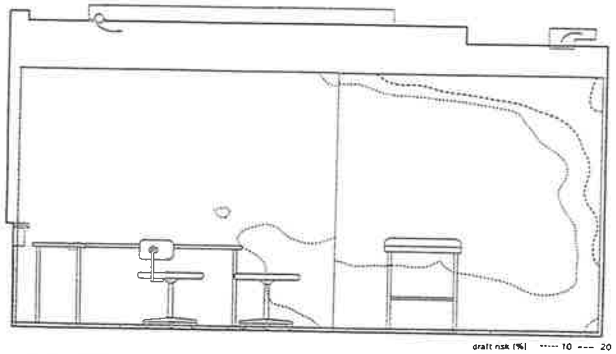

Fig. 4. Measured draft risk (%) (outdoor air temperature - 5 °C)

DISCUSSION

Experiences from this full-scale modelling showed that it is possible by good planning to help prevent faults in design. This experiment has ensured that it is possible to gain desired results with properly planned HVAC equipment, acoustic environment and materials. Special attention has to be paid to the building construction, so that designs are realized as planned.

This kind of modelling can be recommended particularly in cases where several similar rooms are built. Building costs can be saved because of the possibilities of finding alternative, better and cheaper constructions. In cases where planned constructions do not work, repairing or changing the constructions is much more expensive than making full-scale tests.

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DRAUGHT RISK FROM COLD VERTICAL SURFACES

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ABSTRACT

Glazed facades and atria have had a boom in the 1980's as an architectural feature in building design. Natural convective flows from these cold surfaces are in winter time, however, often the cause of thermal discomfort and there is a need for research to improve the design methods.

The objective of the research is to develop expressions for the airflow beyond the floor area, which influences the thermal comfort in the occupied zone.

Measurements of velocities and temperatures are carried out in a two-dimensional test case. They show that the characteristics of the flow in the near floor region are very similar to the characteristics of stratified flows. Expressions have been developed for the rate of decrement of the maximum velocity with distance from the surface and for the maximum temperature difference between the cold airflow along the floor and the rest of the occupied zone.

INTRODUCTION

Cold surfaces often generates thermal discomfort in rooms, due to cold radiation effects and down draught problems caused by the cold natural convective flows from these surfaces. As we design preventive actions we should note that the surfaces may also cause an unnecessary increase in energy consumption. There is a need for research in order to improve design methods for natural convective boundary layer flows, and under which circumstances there will be thermal comfort problems in the occupied zone, and how to solve them considering also the energy consumption?

The development of natural convective boundary layer flows along a vertical plane surface, and the velocity distribution and temperature gradients of such flows, have been thoroughly investigated theoretically and experimentally by several researchers (1,2,3,4).
The interest of the research has, however, ceased at the bottom edge of the surface and only a few researchers (5,6) have investigated what happens to the boundary layer flow as it hits a surface normal to it, here the floor, and continues into the occupied zone.

The objective of the research is to contribute to improved design methods for natural convective flows along cold, vertical and plane surfaces, and especially continue the experimental work (5,6) to develop expressions for the velocities and temperatures in the airflow into the occupied floor area, which influence the thermal comfort in the occupied zone.