An Analysis of a Flexibility Chilled Beam System in Hot and Humid Climate

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Abstract

In a modern office environment, balance is sought between working as individuals and the interaction between employees. For a room system, adaptability means taking changes in the supply air flow, cooling and heating effects and throw pattern of the supply air device into consideration. Chilled beams systems are quite common in temperate climate. With the chilled beams systems, it is possible to reach good indoor air quality in an energy efficient manner. Still, the applications of chilled beam systems in hot and humid climate have been limited. A case-study measurement was conducted to investigate the feasibility of a ventilated chilled beam system in hot and humid climate. Based on the measurements, the condensation in the beam system is possible to prevent and to maintain dry cooling if infiltration is minimized, supply airflow rate is sufficient to extract humidity of people and tuning of the automation system has conducted probably.

Keywords – chilled beams; hot and humid climate; flexibility

1. Introduction

Recent studies have clearly proven the correlation between indoor air quality and the work performance of employees [1]. Similarly, it has been demonstrated that the thermal conditions of the room have a significant impact on the productivity of work [2]. Employee salaries and the potential change in productivity amount to many times the cost of a building technology system. The studies indicate that an investment in a better indoor environment is a profitable one, even with very minor productivity changes [3].

In addition to the indoor environment, the functionality of the workspace significantly affects the productivity of employees. Often a compromise must be made among the needs of the employee, team and organisation when arranging workspaces. Addressing the interaction and privacy needs of employees both of which are important considerations in organisations, it is particularly challenging. In general, it can be stated that, from the perspective of dispersing silent information (views, experiences, intuitions), fully autonomous workspaces do not support the business models of most companies. On the other hand, reducing the autonomy afforded by individual workspaces reduces acoustic privacy, which disturbs concentration.

Organisational changes in most companies are continuous and require flexible changes in work methods and workspaces [4]. The traditional one-person office areas, or cells, and open offices, or hives, seen in traditional offices are today changing into spaces that are more suited to team work, referred to as dens or clubs (Table 1). In addition to this, information technology contributes to independence of time and location, transforming offices more into meeting places for sharing information. The office space must be utilised efficiently, and therefore a dedicated workstation is no longer deemed necessary for a worker who spends only a few hours a day at the office. Working at several workstations and at customer sites is becoming more common.

Table 1. Adapting space types and business processes in office buildings.

Space	Interaction	Autonomy	Operation	Example
Hive	low	low	customer service	call centre
Cell	low	high	support tasks	financial administration
Den	high	low	team work	media
Club	high	high	expert work	consultancy

Layout changes in workplaces are a rule, not an exception. Due to management reorganization, changes in business models, and technological innovations, companies may already change their workplace interior layout once a year. Churn cost is often one of the highest operating costs in modern offices being 330€ to 2000€ per moved person a year [5]. Building services are the major cost generator and a slowing, or even preventing factor in layout changes.

In the Tropical climate, it is important to control relative humidity concurrently with temperature. The majority of air conditioning systems installed in the Tropics are designed based on all-air systems. Ceiling mounted ventilated chilled beam system could be other attractive approaches for improving energy and ventilation efficiency. These systems minimize the quantity of airflow rate handled and have ability to provide a high quality indoor environment. This means that the space requirement of ductworks and air-handling units are much smaller than with traditional mixing systems. This means savings in the structural and building services costs.

This paper discusses the flexibility requirements imposed by changing office processes for a beam system and covers certain solution models that help to improve the adaptability and flexibility of the system as well as the indoor conditions in the room. Also, the feasibility of a ventilated beam system in the Tropical climate is studied using a case-study approach. The

results of a field measurement in the Tropics, served by a ventilated beam system, were discussed.

2. Flexibility in a Beam System

In order to be able to manage indoor environment efficiently through the lifetime of building, it requires performance-based changes in room units and ductwork. Traditional chilled beams cannot be easily used with variable air flow rates. The ventilation ductwork should be designed for constant pressure, which enables demand-based air flow control. Flexibility requires possibility to control both throw pattern and airflow rate in changing conditions.

For maintaining a constant supply air flow (2 l/s per m^2), an adjustment range of 15–30 l/s is required of the room device. This range increases to 15–40 l/s if it must be possible to convert a one-person office room into a meeting room. Together with airflow rate, air velocity conditions should be controlled to maintain draft-free conditions.

Ready adaptability of air flow and space arrangements also increases the need to manage air distribution such that it reflects the various space solutions. It must be possible to reduce the total air flow from a beam in situations where, for example, the room device is close to a partition wall and the distance of the workstation from the wall is short. It should also be noted that, owing to individual differences between people, some people perceive even low air velocities as a draught. This means an increased need to manage the individual room conditions. An efficient way of managing room space air velocities is to reduce the induction ratio of the room device to an appropriate level. Fig. 1 presents the principle of operation for the induction ratio adjustment in a ventilation beam.

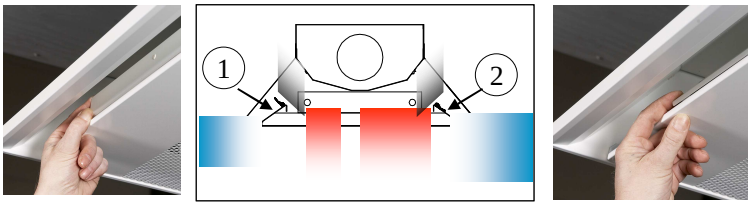

Fig. 1 *Principle behind induction ratio adjustment: 1) induction ratio adjustment on and 2) induction ratio adjustment off.*

Case-studies carried out in laboratories examined the significance of induction adjustment in a situation where beams installed in a suspended ceiling were perpendicular to the window. According to the measurements made [6], induction adjustment could significantly reduce air velocities in the proximity of the employees (Fig. 2).

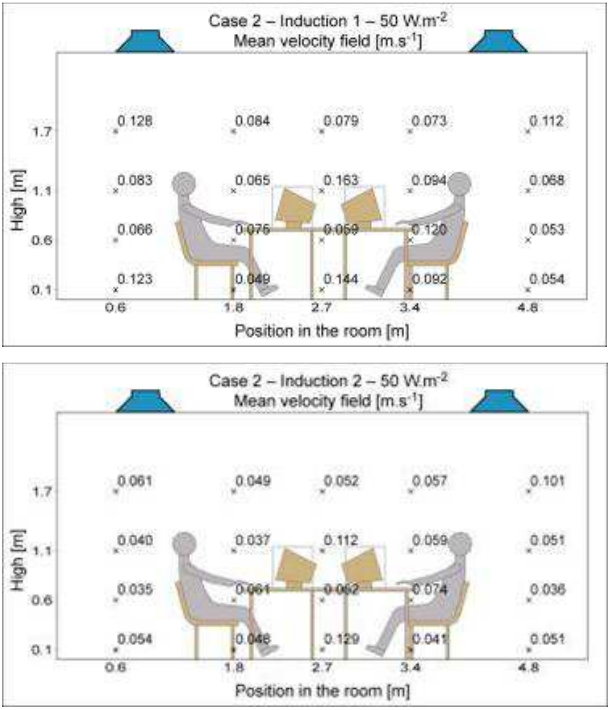

Fig. 2 *Impact of induction ratio adjustment on air velocity in laboratory tests. Upper Image: Induction ratio adjustment off. Underneath image: Induction ratio adjustment on.*

The primary airflow rate of each beam could be adjusted using an air quality control unit. Thus, there is no need to change or plug nozzles of the chilled beam. Air quality controller also allows increasing the airflow rate of a chilled beam - e.g., to meet the ventilation requirements of meeting rooms (up to 4-6 l/s per m^2). Using air quality control unit, it is possible to change easily office to meeting room (Fig.3).

Fig. 3 *Minimum office requirement is supplied through nozzles (left). In case of a high maximum airflow rate, air quality controller is introduced (right).*

3. Performance of Beam System in Hot and Humid Climate

The feasibility of a ventilated beam system is evaluated using field measurement in an office building [7]. The condensation risk during the morning start-up period and operation hours is studied by monitoring room conditions. In the office, two rooms were installed with a ventilated beam system. The rest of office rooms are served by the all-air system. An office of 20 m^2 is located in the perimeter zone where possible air infiltration increase humidity level. The other room is a conference room of 56 m^2, which is located in the central area. This internal room is not affected by infiltration and the main humidity source is from the people. The design conditions are shown in Table 2.

Table 2. The design conditions of the ventilated beam system in the case-study office.

Design Conditions	Conference Room	Office
Indoor Temperature (^oC)	23	23
Relative Humidity (%)	60	60
Room area (m^2)	56	20
Sensible cooling load (W/m^2)	42	89
Number of Persons	20	3
Off-Coil Temperature (^oC)	14	14
Air Flow Rate (l/s,person)	7	11
Water Inlet (^oC)	16	16
Water Outlet (^oC)	18	18

In the measurement arrangement, the room temperature and humidity is measured with portable data logger. The same system is used to measure the supply air and outdoor conditions. The supply air flow rate to the room spaces is measured using a pressure measurement tap of the ventilated beam. The water inlet and outlet temperatures were measured with the thermocouples installed on the water pipe. The good contact of the thermocouples is secured using glue and covered the thermocouples with the insulation. In Fig. 4, it is shown the measurement results of the system during one typical working day.

The room temperatures are 21-23 ^oC in the conference room and about 23 ^oC in the office room. The dewpoint of the conference room is about 17 ^oC and 14.5 – 16.5 ^oC in the office. The dewpoint of the conference and office rooms are quite close the water inlet temperature. However, the water inlet temperature is higher than dewpoint and condensation is not happening.

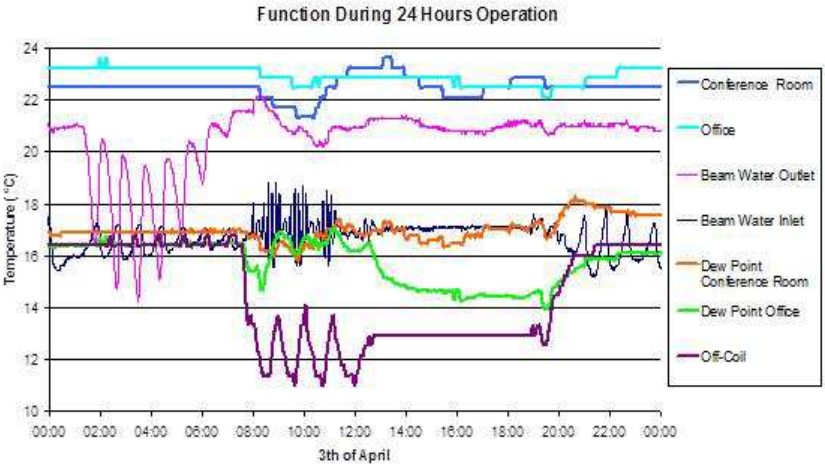

Fig. 4. *The operation conditions in the ventilated beam system during one working day.*

4. Discussion

In a modern office environment, balance is sought between work performed by individuals and in interaction between employees. It must be possible to appropriately combine various work methods, so partition walls and workstations should be flexibly adaptable if they are to best meet the business needs of individual customers.

Adaptability of office space is one of the central requirements in the design of a beam system. The systems must be adjustable to address changed loads and partition wall positions. In design of a room system, this flexibility means taking account of supply air flow, cooling effect, and supply air device throw pattern changes. In addition, adjustability entails requirements concerning room automation, actuators and sensors. It must be possible to adjust the air flow supplied by the room device, which enables managing the maximum and average velocity in the occupied zone and thus reducing the draught risk.

In the Topical climate where the humidity is always high, it is important to maintain the dewpoint of the room space lower than the water inlet to prevent condensation. The most challenging time periods are Monday mornings. In the Tropics, the inlet temperature should be higher to prevent condensation in the ventilated beams. The target temperature and humidity level are the starting point for the system design.

Typically, the target for the room temperature is 23-24 ^{o}C and 60-65 % for the relative humidity. Nowadays, there is trend to rise up the room temperature up to 26 ^{o}C. That reduces the required cooling capacity significantly. It should be that thermal comfort is not restricted to humidity

limit in the indoor air. The humidity can be as high 75 % if the air temperature is within the acceptable level. It should be noted that mould growing should be taken account. The mould growing could be possible if the relative humidity is over 78 % at the room temperature [8].

The conducted measurements indicate that the infiltration could be quite small if the windows frames and doors are airtight. Thus, the night-time generated humidity is possible to ventilate by starting the operation of air-handling unit about 30-60 minutes earlier than water-based cooling. Anyhow, the dehumidified period must be longer and the supply air flow rate should be higher if the building is less airtight.

In the mornings, the air-based cooling should start earlier and after certain time when the humidity level will be at the design level water-based cooling should start. This means that control strategy should be designed taken into account the characteristic of the building. Also, the commissioning and the tuning of the automation system have to conduct probably. In the Tropical conditions, faults in the automation system are much more critical than in the temperate climate.

It should be noted that the supply air flow rate is not necessary need to be outside air. Depending of the application, part of the air flow is possible to take for return air side. The demand of the outdoor air flow rate is most of building codes between 4 – 10 l/s per person.

5. Conclusions

Organisational changes in most companies are continuous and require flexible changes in work methods and workspaces. The traditional one person office areas, or cells, and open offices, or hives, seen in traditional offices are today changing into spaces that are more suited to team work, referred to as dens or clubs. This means that building system should be easily to be adaptable for the needs for continuously changing users. Specially, throw pattern and air flow rate should be easily to be adjustable.

In hot and humid climate, the room design conditions of 23 ^{o}C and 65 % is attainable with the water inlet and the supply temperatures 17 ^{o}C and 14 ^{o}C when the specific supply air flow rate is 10 l/s per person. Together with the previous design parameter and with dehumidified the indoor air properly prior the operation of the water-based cooling, it is possible to maintain dry cooling without any condensation in the ventilated beam system.

Acknowledgment

The heading of the Acknowledgment section and the References section must not be numbered. A The study is supported by Technology Agency of Finland (TEKES) in RYM-SHOK research program.

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