A FIELD STUDY OF A VENTILATED BEAM SYSTEM FEASIBILITY IN THE TROPICAL CLIMATE

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ABSTRACT

Ventilated beams systems are quite common in temperate climate. With the ventilated beams systems, it is possible to reach good indoor air quality with reasonable life-cycle costs. Still, the applications of ventilated beam systems in hot and humid climate have been limited. The main reason for that is high risk of condensation. A case-study measurement was conducted in a typical Singaporean office building to investigate the feasibility of a ventilated 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

Ventilated beams, hot and humid climate, humidity control

INTRODUCTION

In the Tropical climate, it is important to control relative humidity concurrently with temperature. Many studies have been carried out to investigate the effect of humidity on human health and indoor pollution such as fungi, dust mites, particles, bacteria, viruses, pollutant emissions from building materials, respiratory and skin diseases. The effect of temperature and humidity on the perception of indoor air quality has been researched [1]. Decreasing the indoor air temperature and humidity could improve the perceived air quality significantly. The results have shown that the acceptability of indoor air increases linearly with decreasing enthalpy of air.

The majority of air conditioning systems installed in the Tropics are designed based on the mixing strategy. That is, for example, variable and constant volume all-air systems. On correct design, these systems can offer high standards of comfort and air quality. It may be however that they do this at the expense of high running costs.

Ceiling mounted ventilated beam system could be other attractive approaches for improving energy and ventilation efficiency. These systems minimize the quantity of air 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.

In the building process, the initial cost is still the main criterion when making choices between different systems. With life-cycle cost (LCC) calculations, it is possible to get better overview of the total cost. The ventilated beam system was analyzed and compared to other typical system. The LC cost of the ventilated beam was lower than the variable air-volume and fan-coil systems in the temperate climate [2].

In this paper, the feasibility of a ventilated beam system in the Tropical climate is studied using a case-study approach. Field measurements were conducted in two rooms of an office building, located in Singapore, served by a ventilated beam system.

RESEARCH METHODS

The feasibility of a ventilated beam system is evaluated using field measurement in an office building. The condensation risk during the morning start-up period and operation hours is studied by monitoring room conditions.

The measurements were conducted in a typical office building in Singapore. This three-storey-building was initially a light factory. Recently, the floor that was used for study has been renovated.

In the renovation, all internal building materials were replaced and the present open space converted to partly open and partly personal room office layout. There was no retrofitting of the external walls and the windows that improves the air tightness of any part of the building envelope. The windows are a non-openable one panel with metal frame and sealed gaskets. The total area of the office in is 3,970 m^2. In the office, two rooms were installed with a ventilated beam system. The rest of office rooms are served by the mixing system. Figure 1 shows the layout of the studied office floor and pointed out the location of the studied ventilated beam rooms.

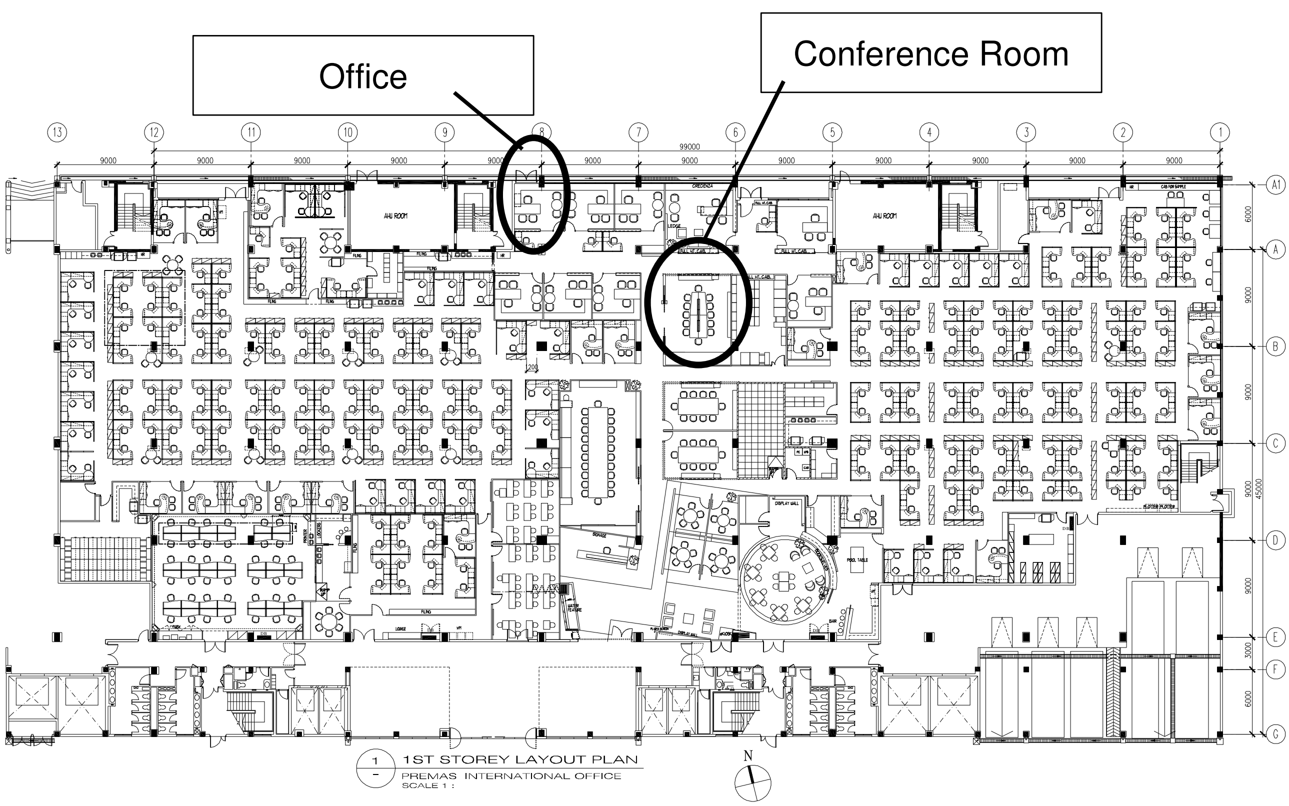

Figure 1. The office layout and the locations of the ventilated beam office and conference rooms.

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. In the office room, there are installed four beams and six beams in the conference room. The length of each beam is 2.1 m.

In the beam system, there is the connection to the supply air ductwork from which the air enters in the plenum of the ventilated beam. Further in the ventilated beam, the air supplied from nozzles induces the room air through water-coil. The mixture of the supply air and induced air is introduced into the room space through longitudinal slots along both side of the ventilated beam.

In the temperate climate, the temperature of the supply air is typically 16-18 ^oC and the water inlet 14-16 ^oC. In the Tropical conditions, the supply air temperature should be designed to be lower and the temperature of the water inlet higher to prevent condensation. In Table 1, it is shown the values of the main design parameters of the system.

Table 1. 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 Load (W)	2,360	1,780
Specific Load (W/m^2)	42	89
Number of Persons	20	3
Off-Coil Temperature (^oC)	14	14
Air Flow Rate (l/s)	147	56
Water Inlet (^oC)	16	16
Water Outlet (^oC)	18	18

The supply air flow rate is totally coming from outside and there is no re-circulation applied in the system. The designed specific airflow rate was 2.8 l/s per m^2 (19 l/s per person) in office and 2.5 l/s per m^2 (11 l/s per person) in the conference room. The return air is extracted to the other air-handling unit, which served other part of the office. The used supply and return air flow rates are equal.

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 portable data logger calculates automatically all requested parameters of humid air e.g. dewpoint and humidity ratio from the measured drybulb temperature and relative humidity. The supply air flow rate to the room spaces is measured using a pressure measurement tap of the ventilated beam. Using the technical specification of the product, the supply air flow rates are determined.

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.

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RESULTS

In Figures 2-4, it is shown the measurement results in the case-study building. The room temperatures are 21-23 °C in the conference room and about 23 °C in the office room. The dewpoint of the conference room is about 17 °C and 14.5 – 16.5 °C in the office. The relative humidity is 65 – 70 % in the office and 70-75 % in the conference room.

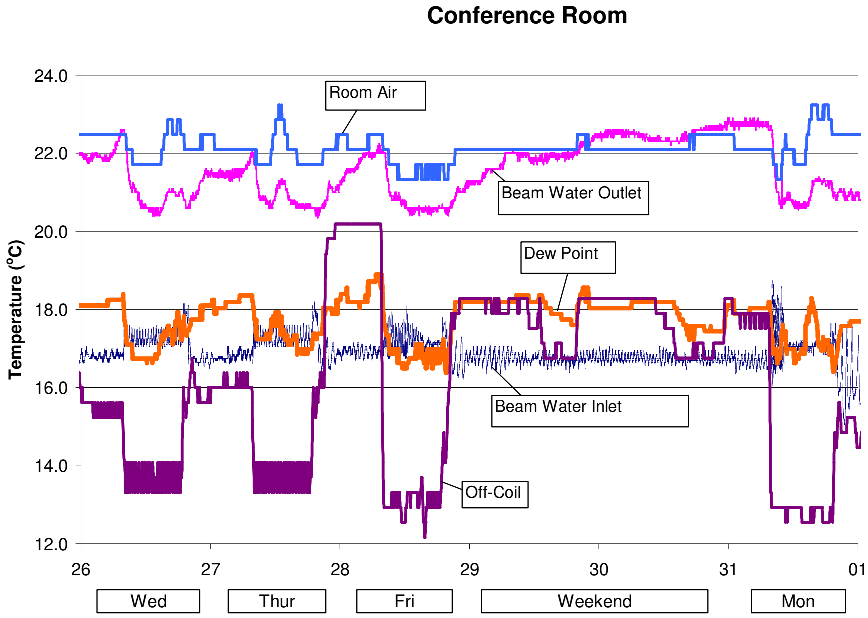

Figure 2. The operation temperatures in the conference room during six days.

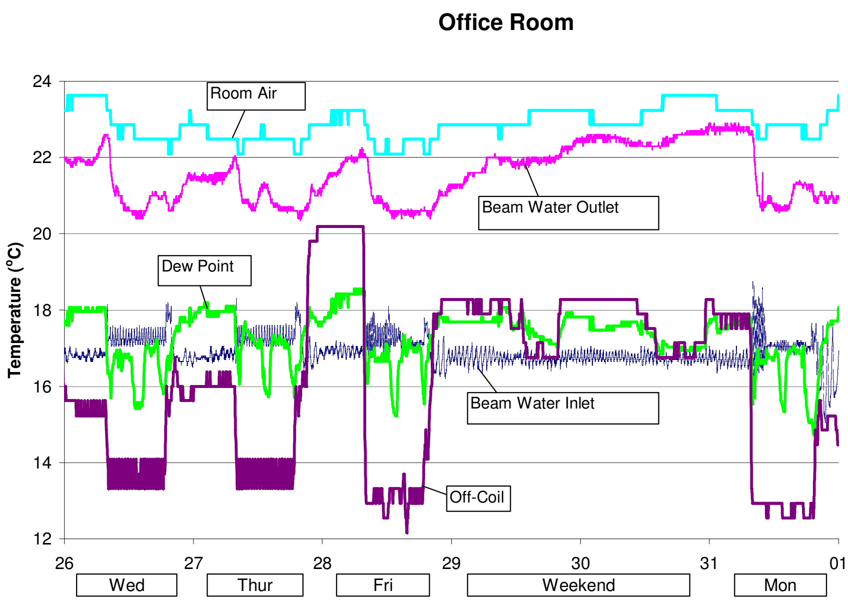

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Figure 3. The operation temperatures in the office room during six days.

During this measurement period, the water inlet and the off-coil temperature temperatures were adjusted to be 17 ^{o}C and 13 ^{o}C. With these set points, the target was to prevent condensation in the beam unit and to get dry cooling. The dewpoint of the conference and office rooms are quite close the water inlet temperature. Anyhow only during short time slot, the water inlet temperature is higher than dewpoint.

The humidity level is high in the room spaces because the supply air flow rate is much lower than the design values due to undersized fan capacity. In the conference room, the airflow rate is 39 % lower than design value an in the office 42 % lower. The actual air flow rate in the conference room is 1.4 l/s per m^2 (7 l/s per person) and 1.7 l/s per m^2 (11 l/s per person) in the office.

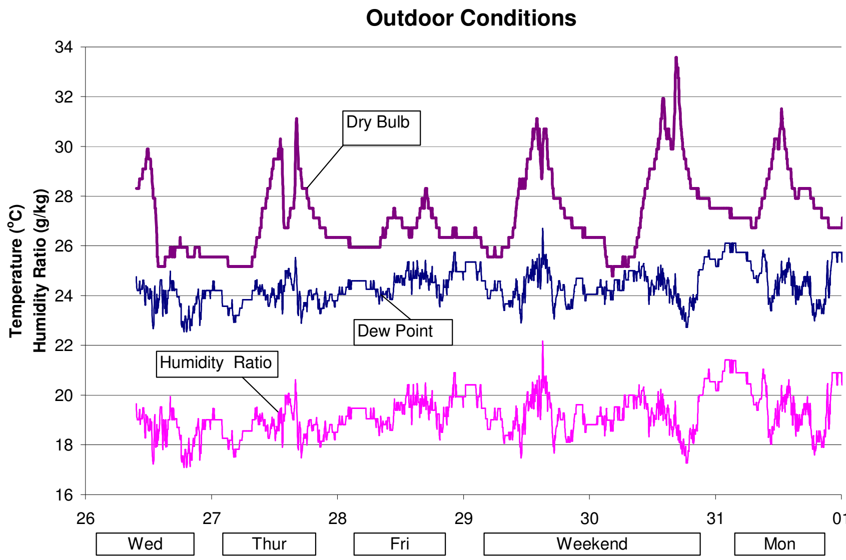

Figure 4. The outdoor conditions during measurement period of six days.

If the supply air flow rate is according designed values, the dewpoint of the room spaces would be notably lower that the inlet water temperature. This means that in this building, where the leakage is limited, it is possible to prevent condensation and to obtain dry cooling during working hours.

It should be noted that the humidity level is not significantly increased during nights. The dewpoint raised up only about 1 ^{o}C during the night-time from the day-time value. As well, during the weekend the humidity level will remain almost constant. This indicates that the infiltration is negligible. The estimated infiltration from the humidity measurement is less than 0.05 1/h.

DISCUSSION

The cooling loads of the room spaces are at the same level in the Tropical climate and in the temperate climate if the direct solar radiation is prevented. The main difference compared is the high outdoor humidity. The main features of the Tropical climate are uniform temperature, high humidity and abundant rainfall throughout the year. In Singapore, the average dew point is about 24 ^{o}C and the humidity ratio of 18.5 g/kg during the nights and 19.5 g/kg in the daytime almost constantly all year-round.

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 period is mornings. In Scandinavia, the suitable water inlet is 14 ^{o}C and 15-16 ^{o}C in the central Europe. In the Tropics, the inlet temperature should be higher to prevent condensation in the ventilated beams.

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 fans 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 are less airtight.

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.

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.

CONCLUSION

A case-study measurement was conducted in a typical Singaporean office building to investigate the feasibility of a ventilated beam system in hot and humid climate. Based on the measurements, the condensation in the beam system is possible to prevent and to reach 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.

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