HEATING "PASSIVE HOUSE" OFFICES IN COLD CLIMATE USING ONLY THE VENTILATION SYSTEM – COMPARISON OF TWO VENTILATION STRATEGIES

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ABSTRACT

In this article we compare to ventilation strategies to heat a "passive house" office building using only the ventilation system. Two ventilation strategies with supply air temperature above and below the current room temperature were compared through a cross over experiment. A questionnaire was used to measure the perceived health and well being. Both strategies documented very good indoor climate with highly positive scores on the questionnaire. The strategy with supply air temperature above the room temperature resulted in a little better perceived health and well being compared to the other strategy.

KEYWORDS

cold climate, heating, questionnaire, passive house, ventilation strategies

1 INTRODUCTION

GK environmental house is the first office building in Norway satisfying the passive house standard (NS 3701, 2012). The building is located in Oslo and has been operational since August 2012. The building is mostly heated by supplying warm air into the rooms through the ventilation system. In addition, active air supply diffusers with integrated presence and temperature sensors are used in each room to control the ventilation rate according to room demand. In this paper, we investigate the potential effects on health and well-being when the heating demand is covered entirely with the ventilation system. The concern is whether air mixing is poor when over-tempered air is supplied into the rooms. In this context, we assessed the perceived indoor climate resulting from two different ventilation control strategies. The first strategy (named strategy 1) resulted in a supply temperature somewhat higher than room temperature, while the second strategy (strategy 2) resulted in a supply temperature slightly below room temperature. Perceived health and well being is measured using a questionnaire.

2 MATERIAL AND METHODS

Both control strategies used consisted in having an initial room temperature of around 21^{o}C when the users arrived in the building. The supplied air temperature at the exit of the Air Handling Unit (AHU) was then controlled depending on the average temperature measured in all the rooms. The curve used to control the supply temperature was different for both strategies and is presented on Figure 1 and Figure 2.

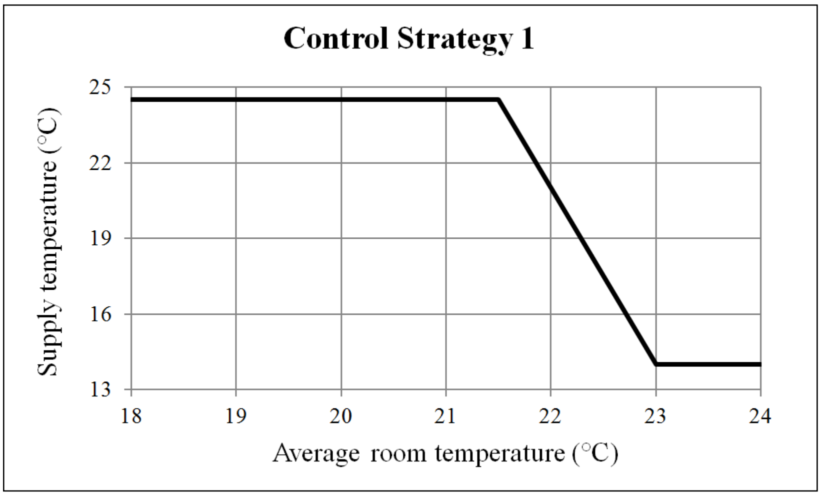

Figure 1: Control of the supply temperature at the exit of the AHU according to average room temperature in the building: strategy 1.

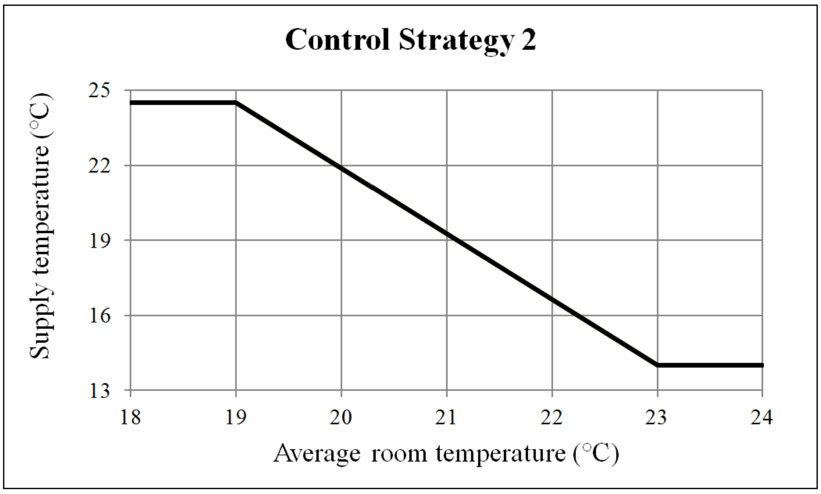

Figure 2: Control of the supply temperature at the exit of the AHU according to average room temperature in the building: strategy 2.

Globally, strategy 1 results in a higher supply temperature than strategy 2.

The two ventilation strategies described above were compared using a cross over design, see Table 1.

Table 1: The plan for the cross-over experiment.

	19th Nov.	13th January		14th January	
Part of building	Both	South	North	South	North
Ventilation strategy	Normal	1	2	2	1
Ventilation temperature control	Normal	Fast (Figure 1)	Slow (Figure 2)	Slow (Figure 2)	Fast (Figure 1)
Ventilation rate [l/s]	Varying	Varying	Varying	Varying	Varying

On the 13th of January the users in the south and north part of building were exposed to strategy 1 and strategy 2, respectively and on the 14th of January the exposing were switched

(Table 1). With such a cross-over design, each user in the building was exposed to both ventilation strategies. On the 19th of November the ventilation were run as normal and the indoor climate were expected to be good. This case was used as control.

A questionnaire was used to measure the users' perceived health and well-being under the different cases in Table 1. The questions are shown in Table 3. On each question the users gave a value between one and ten ranging from very uncomfortable and very comfortable. The sum, *S*, of all the scores for a given user, represents the overall health and well-being for this user. The questionnaire also included health question like whether a used suffered from asthma or cold.

Data from the questionnaires were analyzed using a random effect linear regression model with *S* as the dependent variable. The three cases 19th November, strategy 1 and strategy 2 represent the main independent variable, but also office temperature is included. The office temperature is varying with date and place in the building and including this as an independent variable, we were able to study the effect of the ventilation strategies independent of the room temperature. We also include as independent variables gender and whether the participants suffered from cold or asthma such that we are able to compare the ventilation strategies independent of these factors. We expect that repeated measures from the same user is correlated, e.g. some users are always too cold and some users are always tired, and this is taken into account by including a random effect on the user level in the regression model. Statistical analyses were performed using the program R (R development team, 2013) and the R package lme4 (Bates et al., 2013).

3 RESULTS

Table 2 shows some technical measurements from the experiment.

Table 2: Technical measures.

Date	19.November	13 th January		14 th January	
Part of building	Both	South	North	South	North
Ventilation strategy	Normal	1	2	2	1
Initial supply air temperature (7 am)[°C]	North: 15.9 South: 17.8	24.3	17.3	15.8	24.4
Average room temperature (6 am – 2 pm)	North: 22.1 South: 22.0	21.7	20.7	21.5	21.4
Average supply air temperature (6 am – 2 pm)	North: 15.6 South:15.9	22.8	19.3	21.0	23.4
Outdoor temperature [°C]	4.1	– 10.9		– 5.9	
Outdoor condition	Partly cloudy	Cloudy		Cloudy	

The average supply temperature during the length of the questionnaire (6 hours) as well as the average room temperature are presented in Table 2. We can see that strategy 1 resulted in a supply temperature above room temperature, while strategy 2 resulted in a supply temperature slightly below room temperature . Furthermore, the supply temperature was relatively low on November 19 (15.6-15.9°C). This results from the fact that the outside temperature was relatively high (4.1°C) compared to the tests performed on January 13 and January 14 (–10.9°C and – 5.5°C, respectively). It was therefore necessary to compensate for the internal heat gains by supplying cool air into the rooms.

For each of the three dates in the experiment, 19th November, 13th and 14th January, the questionnaire was sent out to 133 users and we received 46, 35 and 36 answers, respectively.

18 users answered all the three questionnaires. Table 3 shows average score on each question in the questionnaire under the two ventilation strategies and 19th November.

Table 3: Questionnaire with average score under the two ventilation strategies.

Questions	19th November	Vent. strat. 1	Vent. strat. 2
Are you tired?	6.43	7.97	7.46
Does your head feel heavy?	6.83	8.70	7.68
Do you have a headace	8.07	8.77	8.32
Do you feel faint or dizzy?	8.26	9.17	8.49
Do you have problems concentrating?	6.87	8.00	7.61
Do you feel itching or burning in your eyes?	8.39	8.43	8.32
Do you feel hoarse or dry throat?	8.17	8.77	8.39
Do you feel itching or burning in your face or on your hands?	9.20	8.90	8.85
Do you feel nauseous or otherwise unwell?	9.37	9.47	9.58
Is it too warm?	7.76	8.77	8.29
Is there bothersome warmth because of sunshine?	8.26	9.60	8.68
Is it too cold?	8.00	7.57	7.17
Do you feel a draught around your feet or your neck?	9.37	8.93	8.73
Does the temperature in the room vary?	8.85	8.90	8.43
Does the air feel heavy?	7.80	9.00	8.26
Does the air feel dry?	8.02	8.57	8.14
Is there any unpleasant smell?	9.48	9.70	9.39
Do you have a stuffy or runny nose?	9.30	8.50	8.41
Do you cough?	8.96	8.70	8.53

We see that overall the users feel quite well with almost all average scores above eight. We also see that the scores under strategy 1 are higher (more comfortable) than under strategy 2.

Table 4 shows the results from the regression analysis. All answered questionnaires (46+35+36=117) were included in the analysis.

Table 4: Results from linear regression.

Parameter	Estimate	St. err.	df	t value	p value
Vent. strat. 1 (reference: vent. strat. 2)	6.6	2.9	42.5	2.26	0.029 *
19th November (reference: vent. strat. 2)	2.8	2.9	44.9	0.98	0.332
Office temperature	5.1	6.0	46.4	0.84	0.405
Gender male (reference: female)	20.8	6.9	67.9	3.01	0.004 **
Asthma (reference: No asthma)	– 31.1	10.9	69.6	2.83	0.006 **
Cold (reference: No cold)	– 5.3	4.1	49.4	1.28	0.205

Signif. codes: p-value < 0.01:**, p-value < 0.05:*

We see that the perceived health and well-being is significantly better under strategy 1 compared to strategy 2 and that strategy 2 is not significantly poorer than the control autumn (19th November). We also observe that the perceived health and well-being is better for male users and users with no asthma or cold.

4 DISCUSSION

For the winter conditions considered (13 and 14 January), a better perceived indoor climate was obtained for a supply temperature higher than room temperature (strategy 1) than for a supply temperature slightly lower than room temperature (strategy 2).

Furthermore, no significant discomfort regarding perceived indoor air quality was obtained compared to the control case (19 th November). This is an indication that the active air supply diffuser employed display good mixing properties for a broad range of supplying conditions, and that the short-circuiting of the fresh and warm ventilation air is reduced to a great extent.

Therefore, supplying warm ventilation air to cover the heating demand appears to be a relevant solution for office buildings with passive house standard.

5 REFERENCES

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