CAN AIR HEATING ALONE BE USED IN PASSIVE HOUSE OFFICE BUILDING IN COLD CLIMATES? REVIEW OF THE OBTAINED RESULTS

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ABSTRACT

The future is well-isolated buildings with low heating demand. The first office building in Norway satisfying the passive house standard, the GK environmental house in Oslo, was taken into use in August 2012.

Low energy building is the standard for new buildings according to the building codes today, and since passive house standard seems to be included in the building codes in Norway from 2015 there is a great change in the building industry. To meet the low energy concept, the ventilation industry must cope with a massive change from use of installations with constant air volume (CAV) to demand controlled ventilation.

At the same time new technology with active air handling units makes new ventilation systems more flexible to demand controlled ventilation and temperature control, air velocity and draft. The low heating demand in future buildings address the question – is it possible to use simplified heating systems, or even only air heating without any backup heating system, also for the coldest days in Norway and still have satisfied users?

However, given the cold climate in Norway, totally eliminating a backup heating system for the coldest days and only use overheated supply air would be a tough decision without proper documentation.
The R & D project "Simplified demand controlled air conditioning in office buildings with very low heating demand" will develop concepts for ventilation based space heating fit to buildings with very low heating demand, as well as develop documentation on the function and the conditions that must be fulfilled. (www.sintef.no/projectweb/For-Klima). The project period is three years, starting 2013. This paper reviews the results so far.

So far a broad range of studies have been done: Field measurements and intervention studies with user survey on perceived indoor climate at GK environmental house, laboratory measurements, calculations and theoretical evaluations. This paper discusses the results so far after the first winter period. These are preliminary results that will have to be confirmed by further studies next winter.

KEYWORDS

Ventilation, air heating, passive house, indoor climate survey, measurements

1 INTRODUCTION

The future is well-isolated buildings with low heating demand. Low energy building is the standard for new buildings according to the building codes today, and since passive house standard seems to be included in the building codes in Norway from 2015 there is a great change in the building industry. To meet the low energy concept, the ventilation industry must cope with a massive change from use of installations with constant air volume (CAV) to demand controlled ventilation.

At the same time new technology with active air handling units makes new ventilation systems more flexible to demand controlled ventilation and temperature control, air velocity and draft. The low heating demand in future buildings address the question – is it possible to use simplified heating systems, or even only air heating without any backup heating system, also for the coldest days in Norway and still have satisfied users?

Such simplification with air heating was attempted in the '70s. At that time maximum heating demand was 5-10 times greater than is the case with the upcoming building regulations on passive house level. The result was unsatisfactory indoor climate. There is reason to believe that current premises and technical solutions provide significantly better results.

Many building owners are interested in simplified systems, but without good documentations few are willing to go all in. The R & D project "Simplified demand controlled air conditioning in office buildings with very low heating demand" will develop concepts for ventilation based space heating fit to buildings with very low heating demand, as well as develop documentation on the function and the conditions that must be fulfilled. The project period is three years, starting 2013. (www.sintef.no/projectweb/For-Klima)

The first results from the project are presented in this paper.

2 OBJECTS

The object of this paper is to review the project results after the first winter and discuss what these results can indicate.

The main object of the project is to

- **Develop concepts for ventilation based space heating for buildings with very low heating demand**– knowledge about limitations and premises for ventilation with over temperature.
- **Develop knowledge about thermal comfort without traditional draft protection. –** Documentation of actual conditions the coldest days, and document what operation strategy will give the best conditions.
- **Develop documentation of function and premises that have to be met**

Then as a result recommend a documented simplified and cost efficient solution to the future office buildings.

Analyses are mainly based on the following approaches: field measurements, intervention studies with user survey on perceived indoor climate at GK environmental house, laboratory measurements, calculations and theoretical evaluations. Reports from the Central control and monitoring system will be available upon requests.

3 THE GK ENVIRONMENTAL HOUSE

Figure 1: The GK Environmental house and the active air supply diffusor used

Norway's first passive office building - the so called GK environmental house -was taken into use in August 2012. This building located in Oslo is the "home" for GK, one of the leading engineering contractor and service partner in Scandinavia for new and existing commercial buildings. Given the owner, they wanted this building to be a show case. The compact shaped building of 5 stories and 14300m^2 is well analyzed and calculated up front, and Breeam Nor certified as 'Very good'.

The net energy demand is calculated according to NS 3701 (NS 3701:2010) to 64 kWh/m^2/year, and measured delivered energy to 49 kWh/m^2/year according to NS 3031. The energy source for heating is air/water heat pump, heating of hot water is from the refrigerating machine, and there is no cooling of the space areas. The air leakage number (50Pa) is 0,23 and the u values are for external wall 0,14 W/(m2K), roof 0,10 W/(m2K), floor 0.07 W/(m2K) and doors and windows 0,78W/(m2K).

The heating demand is entirely covered by the ventilation system, using active air supply diffusors to adapt to changes in demanded ventilation rate and temperature. The diffusors can regulate the supply area according to the ventilation rate, and then keep a more stable supply air velocity than more traditional supply units. Furthermore, the system can be switched to recirculating air during night time. However, to be sure the owners have installed small electric poles as backup if needed on the coldest days of the year. The office building consists of open plan offices, meeting rooms and some separate offices. The ventilation is now controlled by presence, but can be controlled separate unit by unit. The building management system is designed with detailed logged data.

4 REVIEW OF THE PROJECT RESULTS SO FAR

4.1 Field measurements

The objective is to evaluate the indoor climate in a room heated by high supply temperature, especially on the coldest days of the year. By using a cubic office as a simple test scenario, it is possible to get principal knowledge about ventilation effectiveness and thermal comfort with this kind of solutions that can be transferred to areas with less controlled conditions. The goal is to do the evaluation on the coldest days of the year. Unfortunately the winter 2013/14 was not a very cold winter.

Thermal comfort in a standard cubic room of 9,6m^2 was assessed according to EN 15251 (2007) standard in terms of operative temperature, thermal stratification and draught rate. In addition tracer gas tests (SF_6) according to NS-ISO 12569 were carried out in order to evaluate the ventilation effectiveness in the room.

The test were conducted as 4 different ventilation strategies (test cases)
- Low airflow rate and high supply temperature 1) without and 2) with occupants.
- High airflow rate and low supply temperature 3) without and 4) with occupants.

High airflow rate is based on maximum available airflow, and low airflow rate is the minimum needed for an office with low emitting materials and one person present. Data for the different cases are given in the table below. Further details of method and results are given in (Cablé 2014).

Table 1: Test conditions for the four different cases studied

			Low airflow rate High supply temperature		High airflow rate Low supply temperature	
Measured parameter	**Designation**	**Unit**	**Case 1**	**Case 2**	**Case 3**	**Case 4**
Ventilation rate	Q_s	l/s	17.4	16.8	48.1	49.4
Supply temperature	T_s	°C	31.1	32.0	24.2	24.1
Temperature difference	ΔT	°C	7.5	5.0	1.2	0.8
Outside temperature	T_{out}	°C	-4.8	-7.0	-2.9	-1.8
Heating power	P_s	W/m^2	16.4	10.7	7.6	4.8
Internal heat gains	**P**	W/m^2	3.1	29.9	3.1	29.9

The results fulfil the best category in EN 15251 on operative temperature, above 22,9°C, but gets too high with internal gains as persons and equipment. Preheating of the supplied air above room temperature seems necessary only during colder days or when the offices are empty.

According to the standard (ISO 7730, 2005) a gradient of 4,2°C between ankle and head leads to 10% dissatisfied. For the two cases with low airflow rate, the gradient is 0,8°C and 1,4°C. Higher airflow rate gives an even more homogenous temperature in the room. The stratification seems to be marginally influenced by the presence of the internal heat gains.

Draught risk depends on local air velocity magnitude, temperature and turbulence. Using 10% dissatisfied according to the standard (ISO 7730, 2005), the velocity magnitude should be lower than 0,15 m/s. In case 4 this value is measured at ankle level. The draught risk is limited in this case. All other measurements show much lower air velocity and there is no draught risk. As expected, the air velocity is higher in the caser with higher airflow rate.

The tracer gas study indicates that short-circuiting might occur in an empty room with low airflow rate and high supply temperature. When the rooms are occupied, the mixing increase to perfect mixing and leads to good ventilation effectiveness.

4.2 Intervention studies with user survey

Two different intervention studies on user perceived health and well-beeing have been done in January 2014. The object with these studies is to evaluate which ventilation strategy that gives the best perceived indoor climate.

Each of the intervention studies compared two different ventilation strategies using cross over design. The building was divided in two parts. The first day, one part was exposed to strategy 1 as the other part was exposed to strategy 2. The next day the strategies were switched.

A questionnaire was used to measure the user's perceived health and well-being under the different cases. This was filled out at the end of each day. A reference study was conducted during the autumn. The results were analysed using a random effect linear regression model.

In the first study the initial room temperature was 21ºC. Then the supply temperature was regulated slightly above room temperature for strategy 1, and slightly below room temperature for strategy 2. The outside temperature for the two test-days in January was -10.9ºC and -5.5ºC. More details are given by (Hammer et. al, 2014).

In the second study, a supply temperature of 24ºC and 26ºC was compared with supply temperature of 22ºC, in both cases the room temperature was around 22 ºC. The outside temperature these days were -6 ºC.

Overall the users seem to feel quite well. According to (Hammer 2014 better perceived indoor climate was obtained for a supply temperature higher than room temperature than for a supply temperature slightly below room temperature. No significant discomfort regarding perceived indoor air quality was obtained compared to the control case in the autumn. This is an indication that the active supply diffuser employed display good mixing properties for a broad range of supplying conditions and that the short-circuiting of fresh and warm ventilation air is reduced to a great extent. This is corresponds to the results obtained by the measurements in the cubic office presented above. According to the results from the second study (Cablé 2014) the impact of the different supply temperature were limited.

4.3 Tracer gas measurements for different strategies on overheating, air change rates and placing of exhaust valve

In a Master thesis connected to the ForKlima project, (Aslaksen, 2014) has studied the results of ventilation with heated supply air in a laboratory test room according to NS-EN 442-2. Tracer gas studies were conducted according to NS-EN ISO 12569, in order to analyse the impact of the following parameters on the ventilation efficiency:

- Placing of exhaust outlet
- Air flow rate
- Temperature difference between supply and room air

The tests are done with a supply air temperature of 2, 4, 6 and 10ºC above room temperature with ventilation rates 50l/s, 34l/s, 18l/s and 9l/s. The two first ventilation rates are, as for the field measurements, corresponding to maxima available air flow and ventilation of an office with one person present and low emitting materials. The two other values are chosen to be able to describe a trend in the results.

All tests are done both for exhaust located at floor level and at ceiling level. There were no heat gains, but a dummy and a lamp were placed in the room. Later two tests were conducted with heat gains according to Project report 42 (Mysen et al 2009), and the need for heating was calculated according to NS 3701 for Passive house office buildings.

Table 2: Heat loss and internal heat gains used for calculation of neded heating

Persons:	70W
Lights	5W/m^2
Technical equipment	6W/m^2
Heat loss	0,50W/(m^2*K)

The results show that exhaust at floor level is more favorable than exhaust at ceiling level. The measured ventilation effectiveness with exhaust placed at floor level is 85-90% and higher for all ventilation rates as the heating demand is low. When supply temperature exceeds room temperature with 5-6 ºC the trend is reduced ventilation rate especially for the high ventilation rates.

For exhaust at ceiling level the ventilation effectiveness is around 90% and higher with supply temperature 2-3 ºC higher than room temperature. With supply temperature 4-5 ºC higher than room temperature the curves for the highest ventilation rates goes noticeably downwards and under 80%. With supply temperature10 ºC above room temperature and 34l/s airflow it is as low as 40%. The two lowest ventilation rates keep above 80% until around 6 ºC. All these results are with no internal heating from persons, light and equipment. With internal heating at ventilation rate 34l/s, the ventilation effectiveness increases considerable.

From the results of the calculating of heating demand (Aslaksen 2014) the following rough overview on need for over temperature can be made:

Table 3: Outdoor temperature where different over temperature is needed for different ventilation rates

Over temperature ºC **Ventilation rate**	**1**	**2**	**3**	**4**	**5**	**6**
50l/s	-17	-23	-	-		
34l/s	-14	-19	-	-		
18l/s	-11	-14	-16	-22	-	
9l/s	-9	-11	-12	-14	-15	-16

There is a marginal heating demand before an outside temperature of -10 ºC. At this temperature, a supply temperature of 1 ºC above room temperature is necessary only for the lowest ventilation rates. A supply temperature of 2ºC above room temperature is needed at outside temperature below -23 ºC and 50l/s and at -18 ºC outside temperature with 34l/s. A supply temperature of 4ºC higher than room temperature is likely to be needed first at -22 ºC outside temperature and 18l/s

Average number of the last 10 years of days with outside temperature at the metrological institute at Blindern , Oslo, is by (Aslaksen 2014) as given in Table 4.

Table 4: Average number of days a year with given outdoor temperature

Outside temperature	Number of days
Days with -8 ºC	29,0
Days with -14 ºC	5,7
Days with -20 ºC	0,2

5 DISCUSSIONS

Both the field measurements in the GK environmental house and the laboratory tests show by tracer gas measurements that good ventilation effectiveness is obtained for a broad range of supply temperature and ventilation rate.

When the exhaust is located at floor level, an almost perfect mixing is achieved, while the ventilation effectiveness is a bit lower when the exhaust is located at ceiling level. Furthermore, the ventilation effectiveness is reduced when the supply air temperature exceeds the room temperature with 4-6 ºC. However, according to calculations (Akselsen 2014) with an outside temperature of -20 ºC, a supply air temperature a little higher than 4 ºC above room temperature give good thermal comfort with a ventilation rate 18 l/s, 2 ºC above room temperature with ventilation rate 34 l/s, while a supply temperature of only 1 ºC above room temperature is necessary with a ventilation rate of 50 l/s. According to the statistics the last ten years, an outside temperature of -20ºC has only occurred 2 days in January in Oslo. Results so far indicate that the ventilation effectiveness for these conditions should be around 90% or higher without internal loads, and increasing with internal loads. The risk for short-circuiting seems to be limited.

Furthermore the field studied measurements show that within the criteria of 10% dissatisfied users, the risk for discomfort by draught, and thermal stratification is very low. The only case that might give draught by ankle level is with high ventilation rate, 50 l/s and 2 ºC and internal heat gains. This is an unusual situation, and a condition with high air velocities in the room.

The results from both of the intervention study on the users' perceived health and well-being show marginal difference in score from the reference study. Supplying air at 24 ºC and 26ºC with short periods of heating seem not to influence on the perceived indoor climate compared to supplying air at temperature of around 22 ºC. The results correspond with the measurements showing that this degree of over temperature gives marginal reduction in ventilation effectiveness and nearly no risk for draught and thermal stratification.

6 SUMMARY

The first years of studies in the ForKlima project indicates that demand control ventilation can be used alone to cover the heating demand, thanks to the high performance of the building's envelope and the air supply diffusor. An air supply temperature of 2-4 ºC is necessary for the coldest days of the year, and up to 4ºC the ventilation effectiveness seems to be at a higher level. Good thermal comfort seems possible to be obtained at these conditions. Active air supply diffusors whose supply section varies according to the airflow rate seems to be an important contribution to these results.

These are preliminary results that will have to be confirmed by further studies next winter, and compared to other strategies. It is also to mention that the winter of 2013/14 was a mild winter with a measured minimum of -11 ºC outside temperature.

7 FURTHER WORK

The research and development project ForKlima is now half way through a project period of 3 years. It must be emphasized that the results discussed in this paper are preliminary results. Studies at the GK environmental house will be repeated next winter 2014/15. We then hope for colder outside temperature, to test the solutions under more extreme conditions. New intervention studies will be conducted based on the results and analyzes so far.

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