VENTILATION OF ONE FAMILY HOUSES

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ABSTRACT

In this paper comparisons are presented between three different ventilation systems for a two-storey, one family house using the IDA-version of the computer program Movecomp, which is a multi-cell simulation program used for determining air flows in a building.

The ventilation systems studied are natural ventilation (passive stack ventilation), exhaust ventilation and supply-exhaust ventilation. The model of the building used for the comparisons is based on the assumptions agreed upon by the IEA Annex 27.

The air flow through the building was simulated for different combinations of the parameters outside temperature, wind speed and wind direction. For each set of parameters the air flow through each opening was calculated. Out of this the air change an hour of directly supplied outside air was calculated for each room in the building as well for the whole building.

For the whole building, the air exchange rate always exceeds the nominal value, 0,52 air changes an hour, for the exhaust and supply-exhaust systems. The air exchange rate supplied by the passive stack ventilation varies more, with the lowest value as low as 0,15 air changes an hour.

When looking at the air exchange rate in the individual rooms one get´s a slightly different result. The supply-exhaust system manages to keep a high air exchange rate at all temperatures and wind speeds. The exhaust system on the other hand completely fails to give an acceptable air exchange rate at certain wind directions. It is when the actual room is located at the leeward side that the air exchange decreases rapidly with increasing wind speed. For all rooms the air exchange decreases to zero at these conditions, i.e. the room is not supplied with any outside air directly into the room. The passive stack ventilation system, finally, brings a high air exchange rate for the different rooms at all wind directions and wind speeds as long as the outside temperature is below 0 °C, with the exception of one bedroom which has a very poor air exchange rate at west wind and high wind speeds.

KEYWORDS

Air flow pattern, modelling, natural ventilation, residential buildings.

INTRODUCTION

The air flow through a building and it´s distribution is affected by several parameters, for example the building leakage, the wind speed and direction, the outside temperature and, of course, the type of ventilation system. In Sweden almost all new buildings are equipped with mechanical exhaust or supply- exhaust ventilation systems. For apartment buildings this has been common for the last 40 years and for one-family houses the last two decades. Mechanical ventilation replaced the earlier natural ventilation in order to improve the control of the air flow in the building, increase the air-flow during the warm season and to make heat recovery possible.

The natural ventilation systems used differed somewhat between multi-storey apartment buildings and one-family houses. In apartment buildings the supply air enters through special supply grilles below the windows in the bedrooms and the living room while the exhaust air leaves the kitchen and the bathroom through vertical ducts ending above the roof. One family houses often had simpler systems without special arrangements for the supply air. The buildings were normally so untight that the air could enter the building. The efforts during the 70´s and 80´s to tighten the buildings in order to make them more energy efficient, was followed by a decrease in the natural ventilation flow. Many one family houses with natural ventilation now have an unsufficient air flow.

Today we have a renewed interest in natural ventilation in Sweden. The possibility to use natural ventilation in all kind of buildings is discussed. The reason for this interest is the dissatisfaction concerning conventional mechanical ventilation systems. With an increasing interest in traditional building materials there also follows an interest for traditional ventilation systems, natural ventilation. So far, the interest in natural ventilation is mainly seen among architects and not among engineers.

The purpose of this study is to find relations between the airflows in a building, in the whole building as well as in separate rooms, and the outside climate conditions.

METHODS

Comparisons have been made between three different ventilation systems for a two-storey, one family house. The comparisons were made using the IDA-version of the computer program Movecomp, which is a multi-cell simulation program used for determining air flows in a building. The ventilation systems studied are natural ventilation with supply grilles in bedrooms and livingroom and vertical ducts from bathroom, WC and kitchen (passive stack ventilation); exhaust ventilation with supply grilles in bedrooms and livingroom and constant exhaust flow from bathroom, WC and kitchen and supply-exhaust ventilation with a constant supply flow to bedrooms and livingroom and a constant exhaust flow from bathroom, WC and kitchen. The constant air flow in the exhaust ventilation and supply-exhaust ventilation cases is 30 l/s, equal to 0,52 air changes an hour. The model of the building used for the comparisons is based on the assumptions agreed upon by the IEA Annex 27. To make comparisons between different computer simulation programmes possible, the Annex has decided the characteristics of an apartment in a multi-story building and of a two storey detached house. The latter is used in this work.

The building, see fig 1, has a total area of 83 m^2, which in Sweden is considered quite a small house. The room areas are simplified in a way that the area is 38 m^2 on the bottom floor and 45 m^2 on the upper floor. The building has specified leakage openings at two levels in each room, 0,625 m and 1,875 m above the floor. All the leakage openings are concentrated at the south and the north facades, which in fact makes the building a semi-detached house. In this study, however, two of the totally 18 leakage openings are located to the east facade. These are the leakage openings in the upper hall.

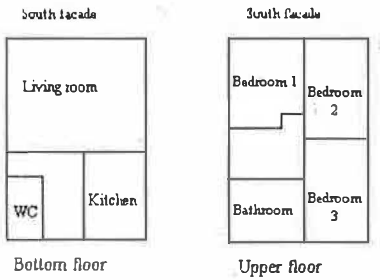

Figure 1 The model building used in this study.

The total area of the leakage openings is chosen to give an air flow equal to 2,5 air changes an hour at 50 Pa pressure difference. For this particular building that equals 4 m^3/m^2, h wall area at 50 Pa. In

Sweden , the Building Code demands a maximum of 3 m^3/m^2, h wall area in new buildings, which makes this building a bit leakier than new buildings in Sweden. The leakage openings are distributed between the rooms in proportion to the room area. The leakage area is assumed to be independent of the ventilation system studied. In reality this may not be true. However, the regulations in Sweden don´t make any difference between ventilation systems in their demands concerning maximum leakage.

The building model studied, contains 8 rooms, three bedrooms and a bathroom on the upper floor, WC, livingroom and kitchen on the bottom floor and a hall with a staircase that connects all the rooms. No leakage openings between rooms, except through the hall, are assumed. The doors between the rooms and the hall are all assumed to be closed except for the door between the kitchen and the hall. The fans used in the exhaust and supply-exhaust case are assumed to have constant flow regardless of the pressure difference. This is according to the Annex 27 assumptions but not the case in reality. As found above the building model used for this study differs from the new buildings in Sweden in many ways. It´s used anyhow since this gives the possibility of comparisations with other computer simulations.

Three models of the building were made, one for each ventilation system studied. The air flow through the models was then simulated . Input parameters were the outside temperature, the wind speed and the wind direction. Outside temperature was varied in steps of 2 degrees in the interval from -30 degrees to +18 degrees. The metereological wind speed was varied in steps of 2 m/s in the interval from 0 m/s to 12 m/s. The wind direction was varied in steps of 45 degrees in the interval from 0 degrees (south) to 225 degrees (northeast).

For each set of parameters the air flow through each opening was calculated. Out of this the air change an hour of fresh outside air was calculated for each room in the building as well for the whole building.

RESULTS

When looking at the air exchange rate for the whole building, one finds that the air exchange rate with the supply-exhaust system always exceeds the nominal value, 0, 52 air changes an hour. The highest value, 1,1 air changes an hour, is reached at 12 m/s and -30 °C at north wind. Figure 2 shows the air exchange rate at south wind.

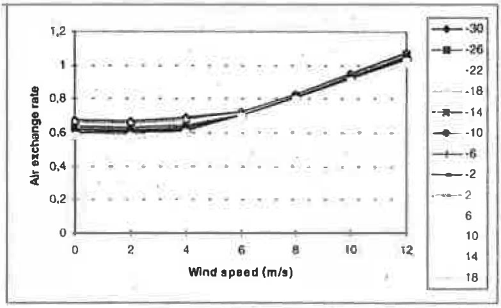

Figure 2 The air exchange rate in whole building as a function of wind speed and outside temperature at south wind. Supply-exhaust ventilation.

The exhaust system reaches a level of ca 1,2 air changes an hour when the outside temperature is -30 °C and the wind speed is 12 m/s at south wind, see figure 3. The air exchange rate exceeds the nominal value at all outside weather conditions.

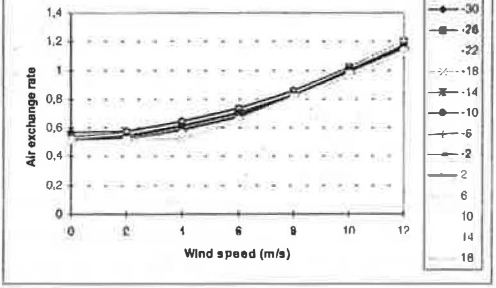

Figure 3 The air exchange rate in the whole building as a function of wind speed and outside temperature at south wind. Exhaust ventilation.

The air exchange rate supplied by the passive stack ventilation system is more spread, with low values at low wind speeds and high outside temperatures. The lowest value is as low as 0,15 air changes an hour and the highest as high as 2,1 air changes an hour. The latter is reached at 12 m/s, - 30 °C and north-west wind. Figure 4 shows the air exchange at south wind.

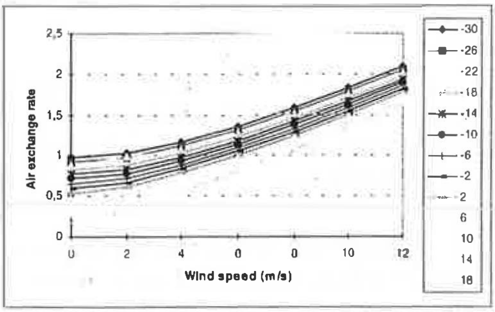

Figure 4 The air exchange rate in whole building as a function of wind speed and outside temperature at south wind. Passive stack ventilation.

When looking at the air exchange rate in an individual room, e.g. bedroom 3, one finds that the supply-exhaust system manages to keep a high air exchange rate, exceeding the nominal value 0,52 air changes an hour, at all temperatures, wind speeds and wind directions, see examples in figure 5 and 6.

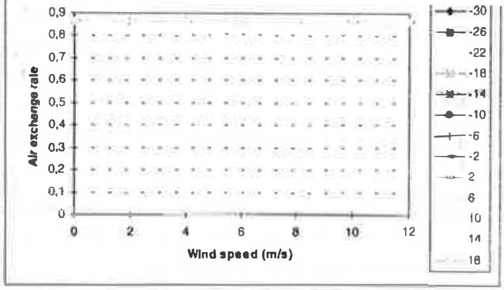

Figure 5 The air exchange rate in bedroom 3 as a function of wind speed and outside temperature at south wind. Supply-exhaust ventilation.

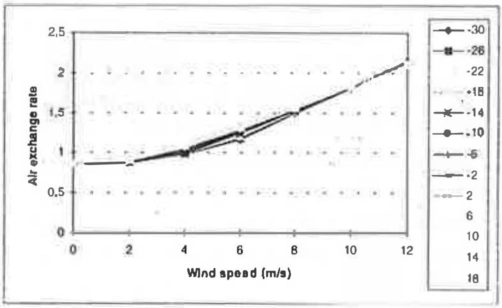

Figure 6 The air exchange rate in bedroom 3 as a function of wind speed and outside temperature at north wind. Supply-exhaust ventilation.

The exhaust system on the other hand completely fails to give a high air exchange rate at low outside temperatures, when the room is located on the upper floor and the wind speed is low. If the room is located on the windward side of the building, the air exchange increases with increasing wind spe d, see figure 7.

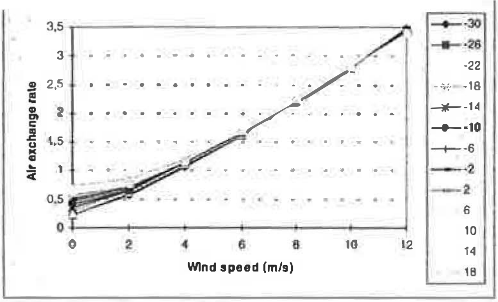

Figure 7 The air exchange rate in bedroom 3 as a function of wind speed and outside temperature at north wind. Exhaust ventilation.

However, if the the actual room is located at the leeward side, the air exchange decreases rapidly at higher wind speeds. Bedroom 3 is, as an example, located on the leeward side of the building when the wind direction is southerly, see figure 8.

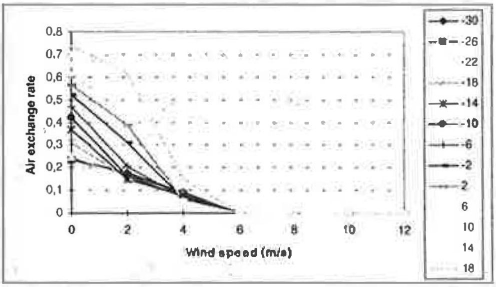

Figure 8 The air exchange rate in bedroom 3 as a function of wind speed and outside temperature at south wind. Exhaust ventilation.

With the passive stack ventilation system, finally, bedroom 3 has a very poor air exchange rate at low wind speeds and high outside temperatures. At west wind, one here finds the same phenomenon as with the exhaust ventilation system, i. e. the air exchange rate drops to zero at higher wind speeds, see figure 9.

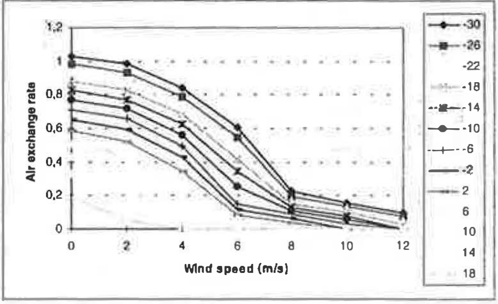

Figure 9 The air exchange rate in bedroom 3 as a function of wind speed and outside temperature at west wind. Passive stack ventilation.

DISCUSSION

When looking at the result for the whole building, the exhaust and supply-exhaust ventilation systems manages to give an air exchange rate exceeding the nominal value, 0,52 air changes an hour, at all outside conditions. The poor results of the passive stack ventilation system, at temperatures over 0 °C and low wind speeds, indicate that the use of a help fan may be necessary under these conditions. The supply-grilles may also have to be closed at low outside temperatures and high wind speeds to reduce the ventilation rate.

The air exchange rate in the individual rooms differs from the rate in the whole building. The supply-exhaust system gives an air exchange rate above the nominal value in all rooms at all outside conditions. The problem is rather that the air exchange is too high, indicating that the leakage level of the studied building is too poor for such a system.

When a room is located at the leeward side of the building, both the exhaust and the passive stack ventilation system have problems at higher wind speeds. With the decreasing air pressure outside the room, the supply of outside air to the room is changed to an exhaust air flow from the room, i.e. the room is not supplied with any outside air directly into the room. With the exhaust ventilation system, the air exchange in all rooms decreases to zero under these conditions. This phenomenon will always appear with an exhaust ventilation system. With the passive stack ventilation system, the phenomenom only appears in bedroom 3 at west wind.

This short study indicates the need for further studies of the air exchange rates in individual rooms. The influence of the leakage level of the building, the leakage between the rooms and the use of bathroom and kitchen fans together with the passive stack ventilation system, are only some of the factors that should be studied.