VENTILATION STRATEGIES AND MEASUREMENT TECHNIQUES

6th AIC Conference, September 16-19 1985, Netherlands

PAPER 22

MONITORING OF VENTILATION AND HUMIDITY IN CRAWL SPACES OF DWELLINGS

J. Oldengarm

Technisch Physische Dienst
(TNO Institute of Applied Physics)
P.O. Box 155
2600 AD DELFT
THE NETHERLANDS

Synopsis

This paper presents some experimental results from field studies on physical phenomena in crawl spaces of dwellings. Particular attention is paid to air transport phenomena that may lead to moisture problems in the living spaces.

1. Introduction

In the Netherlands an increasing attention is paid to moisture and mould problems in dwellings.
It is believed that many of these problems are caused by moisture migration from the crawl space.
Several physical phenomena may attribute to this moisture transport. In this paper we will review briefly the possible moisture transport processes and discuss how these phenomena can be assessed experimentally. Some experimental results will be presented from some field studies.

2. The crawl space

In the Netherlands the majority of the single family houses have a crawl space. A typical construction is shown in figure 1. From practical experience we know that the relative air humidity in crawl spaces is very high in general. A RH of 95% is quite normal. The reason is that in large parts of the Netherlands the ground water level is only a few centimeters below the crawl space bottom surface, while in many cases open water is even present during a large period of the year. Although these facts were known for many years it is just recent that one recognized the crawl space as a potential source for many moisture and mould problems in dwellings. For this reason more effort has been undertaken to collect more practical data, in particular with respect to infiltration of air from crawl spaces to the living spaces.

3. Moisture transport

The following physical phenomena may play a role in moisture migration from the crawl space to the living spaces (see figure 1).:

- Moisture transport by infiltration of crawl space air through air leakages in the ground floor construction.
- Moisture transport by infiltration of crawl space air through air leakages between the crawl space and the air cavity of the facade construction.
- Moisture transport from the crawl space by vapour diffusion or capillary transport through the ground floor construction.
  An increased moisture transport may occur at cold surface areas where condensation takes place.
- Moisture transport from the ground water by capillary transport through the foundation and floor connnections.

Factors that influence these moisture transport phenomena are the outdoor and indoor climate parameters (temperature, air humidity, wind pressure, etc.) and the physical properties of the building materials and the building constructions used.

4. Experimental techniques

Several experimental techniques are available to assess the relative importance of the different physical phenomena in practical situations. For the continuous measurement of moisture content of air in different spaces we have developed a specific measuring system as shown schematically in figure 2. The basic elements in this system are an electronic dew point sensor and an air channel selector consisting of remotely controlled valves. A personal computer is used to control the air sampling and to collect and process the measured data.
Another experimental technique is the pressurization test, as shown in figure 3, for the assessment of the air tightness of the crawl space.

5. Results from some experimental field studies

5.1 The Delft project

In this project the crawl space of a terraced house has been monitored during one heating season. One of the striking phenomena observed was the stratified nature of the crawl space air. Figure 4 shows the air flow pattern that has been observed. The ventilating air flow consists of layer of relatively cold air moving along the ground surface of the crawl space. As a result of this the vertical temperature profile takes a form as shown in figure 5. Because of this stratification one should aspect a low convective heat transfer from the lower floor surface to the crawl space air. This has been confirmed by heat flow measurements as illustrated in figure 6.
To study the ventilation of the crawl space simultaneous measurements have been made of wind speed and pressure differences across the ventilation channels located in the facade. The wind speed was measured at about 1 m above the roof level of the house. The wind pressure coefficient has been determined as follows. First the measured wind speed is decomposed into two components as shown in figure 7.
Then a regression analyis can be made for ΔP and V_L as shown in figure 8.
Next a regression is made between the measured wind speed and the meteorological wind speed at a neighbouring weather station (see figure 9) in order to find the wind pressure coefficient which is related to the meteorological wind speed.
Finally, we are able to calculate the air change rate of the crawl space as a function of the meteorological wind speed. The result is shown in figure 10.
More details of the Delft crawl space monitoring project are found in [1].

5.2 The Katwijk project

In this project the crawl spaces of two houses have been monitored during several weeks.
The purpose of this project was to investigate the effect of a new

product that claims to be a solution for moisture problems caused by high humidity levels in crawl spaces.
The product consists of polyethylene bags filled with polystyrene pellets and hence forms a combination of insulation and a vapour barrier. Some experimental data collected in this project are shown in figure 11, 12 and 13.
Figure 11 shows the results of pressurization tests at the crawl space. The results indicate that the crawl space is not as air tight as expected. Further inspections revealed the presence of cracks between the ground floor construction and the cavity space of the facade wall. Consequently, air transport is possible between the crawl space and the wall cavity.
Figure 12 shows some measurement results of pressure differences. An important conclusion is that the living space always shows an underpressure of a few Pascals with respect to the crawl space.
Finally, figure 13 shows the daily avarages for the moisture content of air in different spaces as measured by the system shown in figure 2.
More detailed results will become available in the near future.

6. Concluding remarks

In the Netherlands there is a growing interest in the building physics of crawl spaces, because they are believed to be the cause for many moisture problems in dwellings.
The results of field studies presented in this paper are the first steps for a better understanding of crawl space physics and its influence on the indoor climate of dwellings.
More field work is needed, in particular with respect to remedial treatments, that may help to solve moisture problems.

References

[1] "Een kruipruimte thermisch aangemeten"
(in Dutch).
Published by Stichting Bouwresearch, P.O. Box 20750,
3001 JA Rotterdam, The Netherlands.

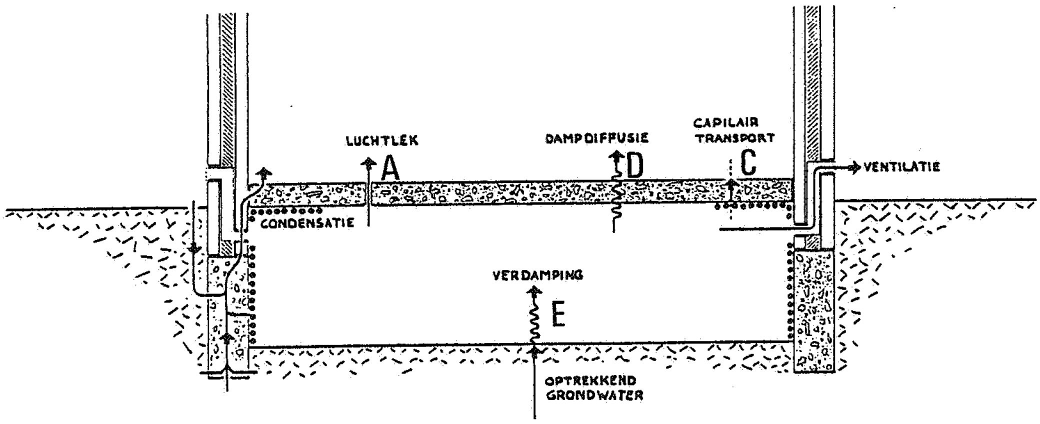

Figure 1: Moisture transport mechanisms.
A = air transport; D = water vapour diffusion;
C = capillary transport; E = evaporation of water.

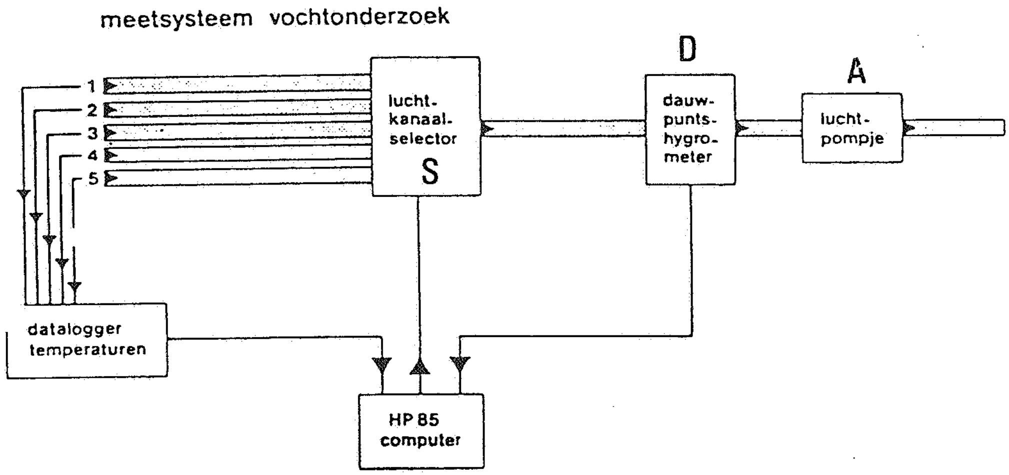

Figure 2: Multi-channel automated measurement system used for moisture analysis in field studies.
A = air pump; D = dew point hygrometer; S = air sample selector.

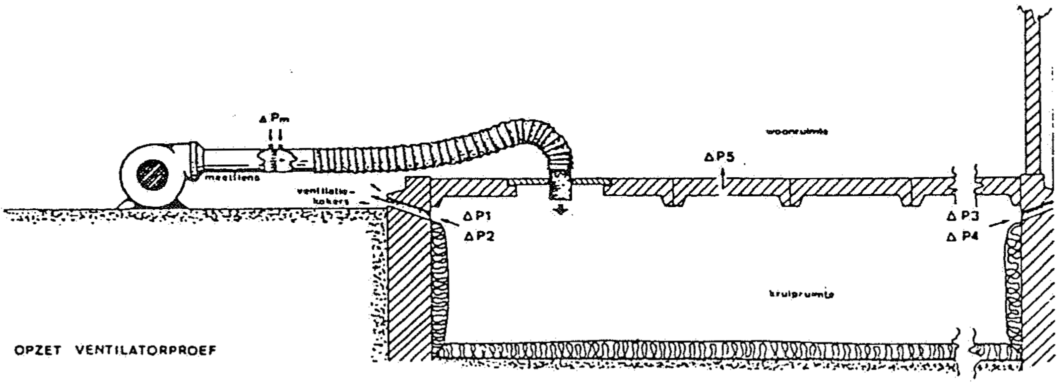

Figure 3: Pressurization test of the crawl space.

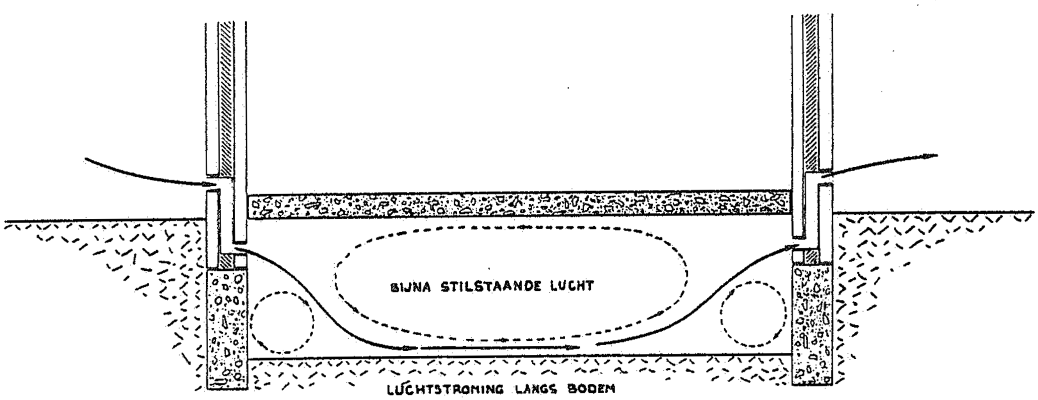

Figure 4: Observed air flow pattern in winter conditions.

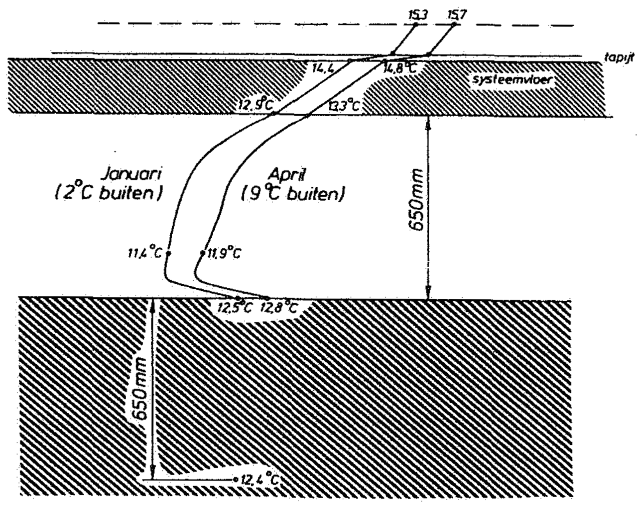

Figure 5: Measured temperatures of the crawl and the ground floor construction. The values shown are monthly averaged temperatures for January and April.

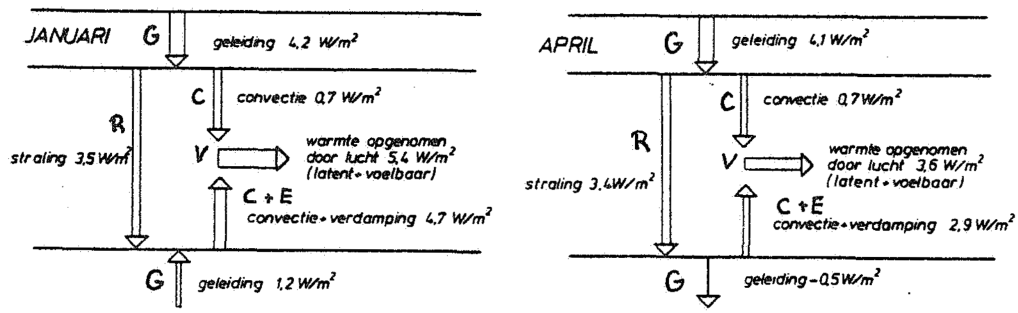

Figure 6: Heat flows in the crawl space.
G = conduction; C = convection; R = radiation; E = evaporation; V = ventilation.
Monthly averaged values are shown.

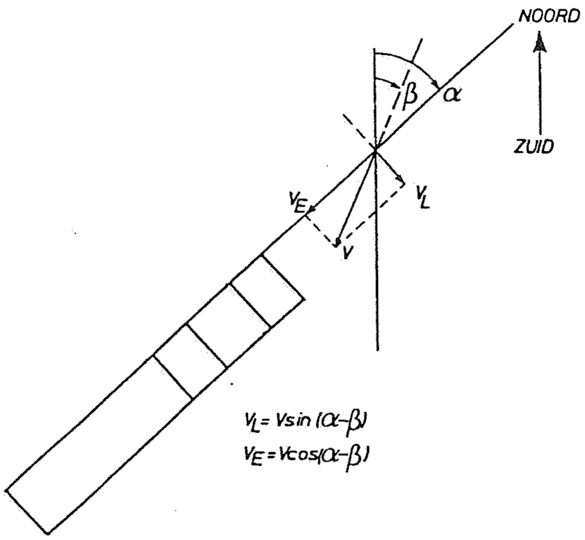

Figure 7: Decomposition of the wind velocity vector.
α = orientation angle of the facade with respect to the north; β = wind direction angle; V_E = wind velocity component along the facade; V_L = wind velocity component across the facade; V = wind speed.

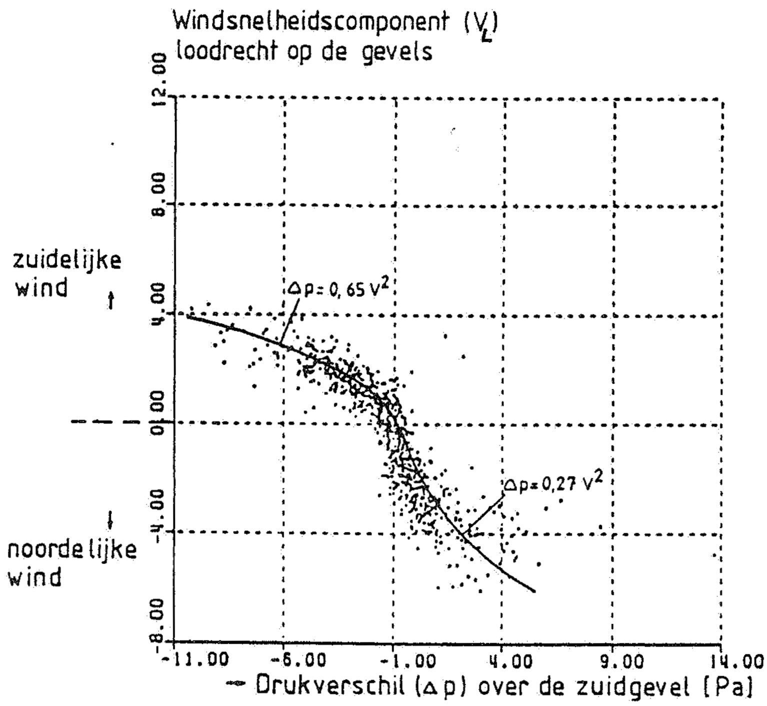

Figure 8: Correlation of pressure difference on south facade (ΔP) against the wind velocity component (V_L).

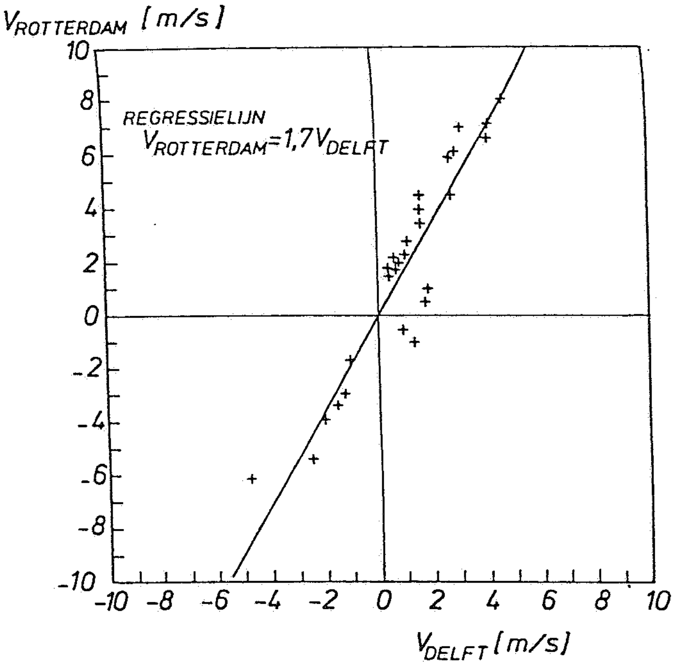

Figure 9: Regression of wind speed measured at roof level (V_{delft}) and the meteorological wind speed data from a neighbouring weather station ($V_{rotterdam}$).

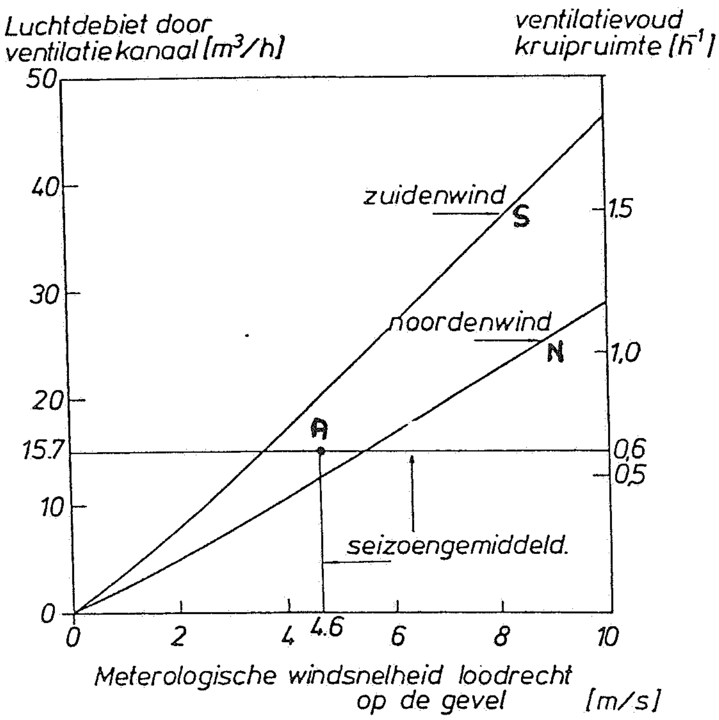

Figure 10: Calculated air change rate of the crawl space expressed in $[m^3/h]$ (left scale) and in ach $[h^{-1}]$ (right scale) as a function of the meteorological wind speed.
S = south wind; N = north wind; A = averaged value for the heating season.

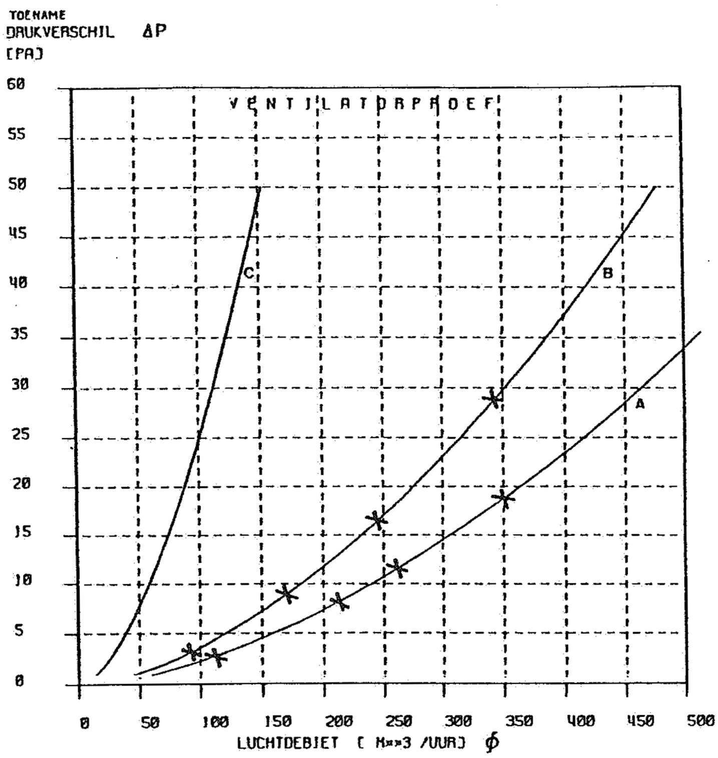

Figure 11: Results of a depressurization test of a crawl space. A = ventilation channels open; B = sealed ventilation channels; C = A-B = ΔP-ϕ curve for the ventilation channels; ϕ = air flow rate.

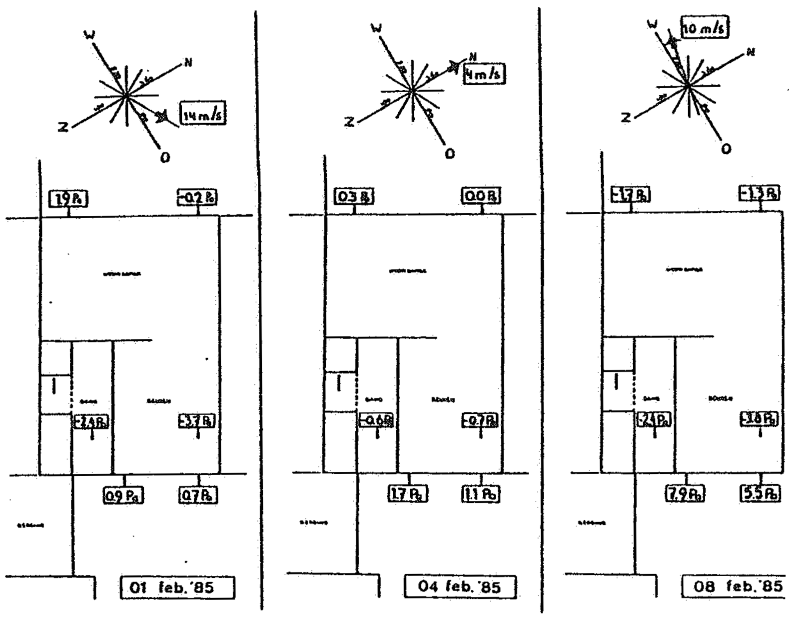

Figure 12: Observed pressure differences (with the crawl space as reference) at different locations for different wind speed situations.

Figure 13: Moisture content of air in [g/kg] for:
A = outdoor air; B = living space; C = crawl space.
Daily averaged values are shown.