Available online at www.sciencedirect.com
ScienceDirect
Building and Environment 42 (2007) 3708–3716
BUILDING AND ENVIRONMENT
www.elsevier.com/locate/buildenv

# Airflow performance of ventilated sub flooring system

Targo Kalamees*, Jarek Kurnitski, Tapio Helenius

*HVAC-Laboratory, Helsinki University of Technology, PO Box 4100, Fin-02015 TKK, Finland*

Received 14 June 2006; received in revised form 3 August 2006; accepted 26 September 2006

**Abstract**

This study analyses the airflow performance of a ventilated sub-flooring system that is only 3 mm thick in laboratory and field conditions and with analytical modelling. Measurements and calculations showing good agreement were allowed to determine resultant equations for the sizing of the systems. It is shown that the design airflow keeps the floor under negative pressure, which prevents the penetration of odours and other contamination leakage to indoors. The design recommendations for ventilated sub-flooring systems are given. In the field study, the performance of the wall application of the system was shown. A quality assurance method was developed to ensure the required airflow in the ventilated sub-flooring system. Possible air leakages of the system can be found with a smoke detector and by real air-intake flow measurements to the floor made with an electronic soap film calibrator.


*Keywords:* Slab-on-ground; Ventilated sub-flooring system; Indoor air quality

## 1. Introduction

Slab-on-ground is a well-used building solution in Finland. The slab on the ground is in contact with the draining layer or soil and under complicated hygrothermal conditions. When not properly applied, moisture damage in slab-on-ground structures may result, leading to mould growth, chemical reactions and material emissions associated with an unhealthy indoor climate. According to Sundell et al. [1], low-rise buildings with a concrete-slab-on-ground type of foundation are associated with higher sick building syndrome (SBS) risks. The Finnish Pulmonary Association studied 429 detached houses during 1996–2002 [2] and found that 23% of microbiological damage was related to the base floor. According to Partanen et al. [3], in 25% of all detached, semidetached or terraced houses, the slab on the ground had some degree of damage caused by moisture. Ruokojoki and Mynttinen [4] reported that 25% of moisture and mould damage in public buildings (schools, health-care centres, day-care centres) was related to the slab on the ground. According to Leivo and Rantala [5], typical moisture failures of slab-on-ground structures in Finland were due to the lack of a capillary breaking drainage layer under the slab, lack of thermal insulation, and incorrect placement of the vapour barrier. In addition to the moisture problems, the soil may be a source of radon, metan and many volatile organic compounds (VOC) that may enter indoors through the slab on the ground.

Sub-slab depressurization is one of the most effective methods of lowering radon levels in many cases. Rydock and Skåret [6] demonstrated a sub-slab depressurisation system that originally was developed for the control of radon could also to be used to ensure acceptable indoor air quality in new buildings located on or near VOC-contaminated ground. Harderup [7] investigated mechanical ventilation of existing joist floor construction with moisture-related problems, where one or more centrally placed exhaust fans were connected to the joist floor directly by pipes, while air was free to flow in a two-dimensional air space between the floor surface and the insulation below.

Slab-on-ground is the standard construction in cellar solutions. In existing buildings, there is a growing need to take into use existing cellar rooms. In this case, the boundary conditions of the slab on the ground and of the requirements for cellar rooms will change, making

*Corresponding author. Tel.: +358 9 451 3609; fax: +358 9 451 3611.
*E-mail address:* kalamees@uninet.ee (T. Kalamees).

0360-1323/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.buildenv.2006.09.007

reconstruction work necessary. Where there are cellar walls and the floor works as a foundation, there are usually only limited possibilities of making major changes to them. There is need to find technically operative and cost-effective solutions that remove odours and contaminants or dry out moisture to guarantee indoor air quality in rooms with a slab on the ground. A ventilated sub-flooring system is one possible repair solution to the problem of improving the indoor climate of floor and wall constructions. It is recommended to use this as the "last possible solution" when other methods, such as a new drainage system or moisture insulation, have not been successful or cost effective. In the case of existing buildings, it is often necessary that the additional sub-flooring system has minimal thickness. Less thickness means a higher-pressure drop in the system and sets higher requirements for system performance.

This study analyses the airflow performance of one commercial application of ventilated sub-flooring systems. A 3-mm thick ventilated sub-flooring system is studied in laboratory and field conditions and by analytical modelling.

## 2. Methods

### 2.1. Description of the studied ventilated sub-flooring system

In the studied ventilated sub-flooring system, a ribbed rubber mat separates the indoor air from the contaminated sub floor. The mat and airflow collectors at both ends of the floor should provide the airtight system. The system is equipped with a mechanical exhaust ventilation system to guarantee the negative pressure in the ventilated floor. With negative pressure, odours and contaminants, as well as moisture, are ventilated out of the building. The air intake is on one side of the floor, while the air exhaust is on the other side. The air intake may be equipped with a filter. Fig. 1, left, shows the performance of this type of ventilated sub-flooring system: 1. air intake; 2. supply airflow collector; 3. ribbed rubber mat; 4. exhaust airflow collector; 5. exhaust air pipe. Fig. 1, right, shows the scheme of the airflow collector. Technical parameters of the ribbed mat of the studied ventilated flooring system are shown in Table 1.

### 2.2. Laboratory test setup

A test floor $3 \times 5$ m was built in the laboratory to study the airflow performance of the ventilated sub-flooring system. The test floor was built on the wooden frame that was covered with 25-mm thick plywood boards. On the plywood, a ribbed mat was installed so that the grooves (1.5 mm high air grooves) were facing upwards. This reverse installation order was used for visualisation purposes as the ribbed mat was covered with 5 mm plexiglass. The test floor size was $5.02 \times 3.05 = 15.3\,m^2$. To guarantee an airtight correct contact between the ribbed mat and plexiglass, a load of $8\,kg/m^2$ was placed on the floor. Air intakes and exhausts were in each corner of the test floor. There were airflow collectors at both ends of the test floor. Air exhaust pipes were at both ends of the exhaust airflow collector. The air pressure difference

Table 1
Technical specification of the ribbed mat

| Characteristic | Value |
|---|---|
| Thickness | 3 mm |
| Roll width | 120 cm |
| Material | SBR rubber |
| Surface material | Polyester fabric |
| Weight | $4.25\,kg/m^2$ |
| Diffusion density | $2.5 \times 10^6\,s/m$ |
| Max. allowable load | Short-term load $50\,kg/cm^2$ |
| | Long-term load $25\,kg/cm^2$ |
| Groove height | 1.5 mm |

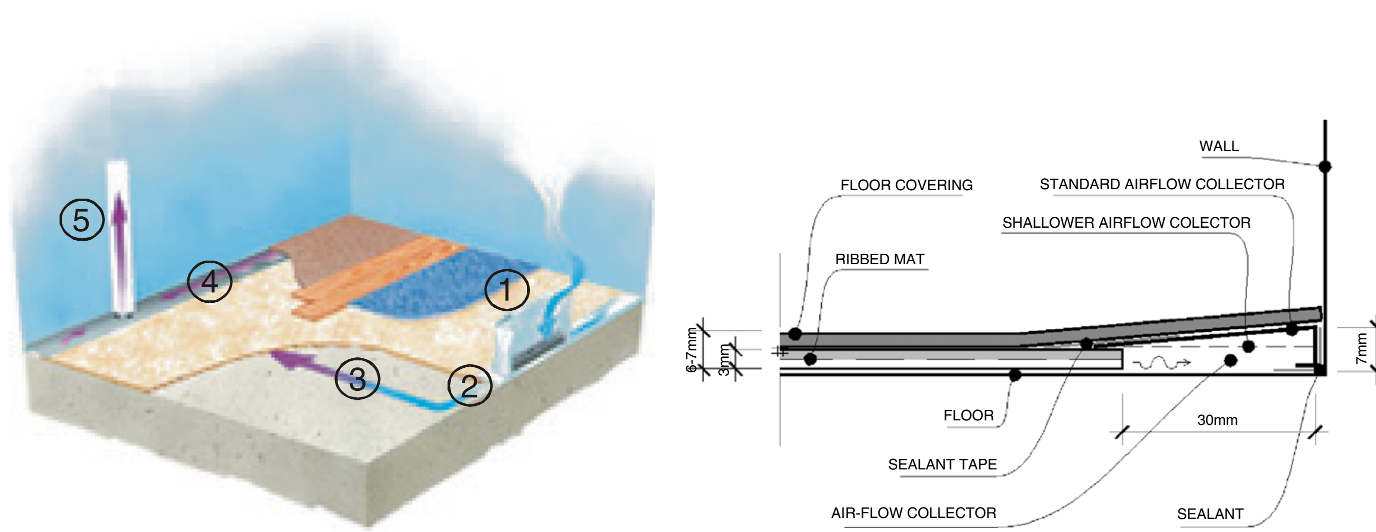


Fig. 1. The principle of the ventilated sub-flooring system (left) and airflow collector (right).