Microbiological Aspects of Slab-on-ground Structures

Virpi Leivo[1] and Jukka Rantala[1]

Abstract:

Coarse-grained fill or drainage layers beneath slab-on-ground structures are warm and moist throughout the year. These conditions are favourable for microbe growth. Often in Finland the high microbe content of the soil layer beneath the ground slab is interpreted as a sign of a moisture failure. The objective of this paper was to determine the microbiological conditions beneath a ground slab during the lifespan of seasonally heated buildings. The objective was achieved by performing long-term field tests on new buildings in Southern Finland and a series of in situ surveys on already established buildings around the country.

According to the test samples taken from 44 buildings of different age and purpose of use, microbe growth is very common in fill layers. Fungal or bacterial growth, in general, was detected in 98 % of the test specimens taken beneath the ground slabs of heated buildings. Indicator species, either fungal or bacterial, were detected in 79 % of the specimens. Also, the average concentration of the detected microbes was high. Yet, no moisture damage related to the ground floors had ever been detected or indoor air problems recorded in the case buildings. The high microbe concentration in the fill layer beneath a ground slab is not a sign of moisture damage, but a normal boundary condition related to the existing thermal and moisture conditions at these layers.

Keywords: microbes, slab-on-ground structure

1 Introduction

Several research series concerning thermal and moisture behaviour of the slab-on-ground structures have been made over the years at the Tampere University of Technology. Thermal and moisture conditions beneath slab-on-ground structure during the first year after construction [1] as well as both capillary and hygroscopic equilibrium moisture content (EMC) curves for typical Finnish coarse-grained fill and drainage materials [1,2] have been determined in previous studies. The results of these studies indicate that the temperature of the fill layer next to the slab structure is relatively high throughout the year. The measured temperature beneath thermally insulated slab varied generally between +12 … +16 °C, depending on the thermal resistance of the slab itself, the outdoor temperatures and the thermal conductivity of the surrounding soil mass. It seems obvious, that at least the thermal conditions at the fill layers under a slab-on-ground structure are favourable for the microbe growth.

In recent years the regulations for indoor air conditions have become tighter, and the new limit regulations allow less and less impurities in our room air. At the same time, the improved methods of measurement are able to detect lower concentrations of detrimental microbes and MVOC in the air. However, the source of the detected MVOC is not always distinctive. Often the high microbe content of the fill layer beneath the ground slab is the easiest scapegoat. The high concentrations of microbes in these layers are interpreted as a sign of moisture failure of the slab-on-ground structure. One of the main objectives of this study was to prove or disprove this assumption.

The objective of this study is to determine the moisture and microbiological conditions beneath a ground slab during the lifespan of seasonally heated buildings. The objective was

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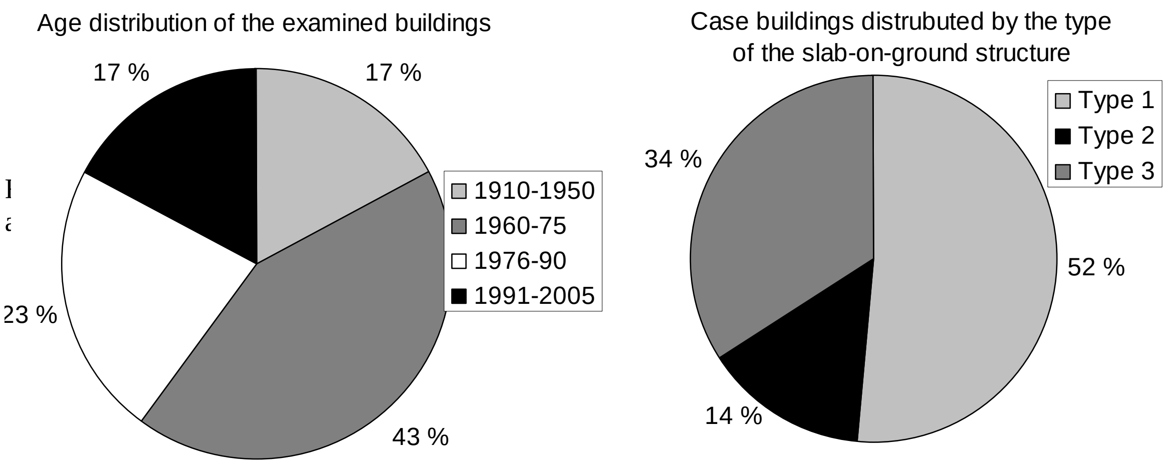
achieved by a series of 49 in situ surveys on already established buildings around the country.

2 Case buildings

The research included 35 individual buildings in 7 different cities in Finland. The random sample included different types of buildings, such as schools, day-care or health centres, apartment buildings, etc. The construction period of the structures differ from 1910 to 2005. The age distribution of the cases is presented in Fig. 1.



a) by age distribution b) distribution by the type of slab structure

Fig. 1 Characteristics of the 35 individual case buildings of the research

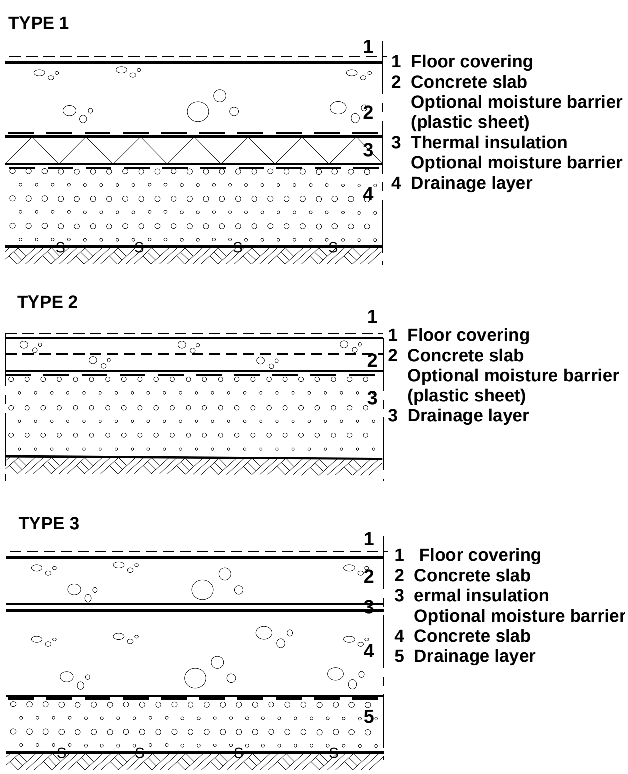


Fig. 2 The three basic types of slab structures detected in the field survey.

Three different basic types of slab structures were detected in these 35 buildings. The most typical structure, type 1, included an in situ cast concrete slab with an underneath thermal insulation layer, most typically an EPS (expanded polystyrene) layer with a varying thickness (Fig. 2). The moisture barrier of plastic sheeting, if used, was placed either above or below the thermal insulation layer. According to existing Finnish building regulations no moisture barrier is required to be placed under the slab structure. All of the slab structures in new buildings were this type. Type 2 was the most common in the older structures and does not include an thermal insulation layer. The third type of structure, type 3, was a so called double-floor structure, where a lower thicker slab was employed for bearing or for transferring loads to the supporting ground piles. Various materials were used between the lower and upper slabs: thermal insulation, plastic sheeting, a bitumen coat or paper (Fig 2). The distribution of the case structures between these three slab types is presented in Fig. 1.

3 Testing procedure

A hole with a diameter of 100 mm was drilled through the concrete slab and 2 samples of the fill soil material were taken and stored in water and airtight plastic bags. The first sample was used for the determination of the water content by measuring the weight loss of the sample by oven drying. The other sample was incubated in the laboratory for the quantitative analysis where the genus and the species of the microbes were identified. The culture medium was a tryptophan-yeast-glucose-agar mix for the bacteria culture and a malted infusion-agar mix for the fungi culture. The total number of bacteria and fungi were determined, as well as the number of indicator species in any individual specimen.

The fungal colonies were counted after 7 days of incubation (at +25 °C), and bacteria were counted after 14 days of incubation. The results are given as the number of detected colony-forming units per a gram of the soil material (cfu/g). The detection limit value was 45 cfu/g.

The fungal genera were identified microscopically and classified as indicator species and other fungus. An indicator species is a microbe that does not usually exist in undamaged building materials. The occurrence of these species in a material sample suggests that the material and the building have suffered moisture damage of some kind. The microbes used as indicator species vary in different countries and laboratories, but in this research the species listed in Baarn 1992 (Samson et al. 1994) and in the WHO 2002 list were monitored. Some fungal species, such as *Acremonium* and *Oidiodendron* have been nationally added to the list based on findings at moisture-damaged buildings in Finland. The bacteria were classified as *Actinomycetes* and other bacteria. The *Actinomycetes* bacteria are also classified as indicator species.

4 Water and moisture content of fill layers

Water content inside the fill soil usually varies in different levels of the layer. This is due to the grain-size distribution and the capillary properties of coarse–grained fill materials. The water content and the relative humidity at the upper part of the layer form the conditions determining the moisture behaviour in the structural layers above. In this research, the water content of fill layers was determined at the fill/slab interface using the weighing–drying–weighing method. The moisture content has been presented as a percentage of the dry weight of soil. The typical density of the coarse-drained soil was between 1500 to 2100 kg/m^3. The results of 33 individual specimens in 33 different buildings are presented in Fig. 3. The sampling date was in late winter/early spring in February – March, while the ground is still in frost and the ground water table is at its lowest. Thus, the determined water contents can be treated as the annual minimum values.

According to the results (Fig. 3) the measured water content of the samples in almost every single case was higher than the EMC of the material in high relative humidity (RH ≈ 100 %

⇔ w < 0,5 % by weight) [2]. Thus, the relative humidity of the fill layer beneath a slab-on-ground structure is very high throughout the year, including the winter months and the heating season for the buildings.

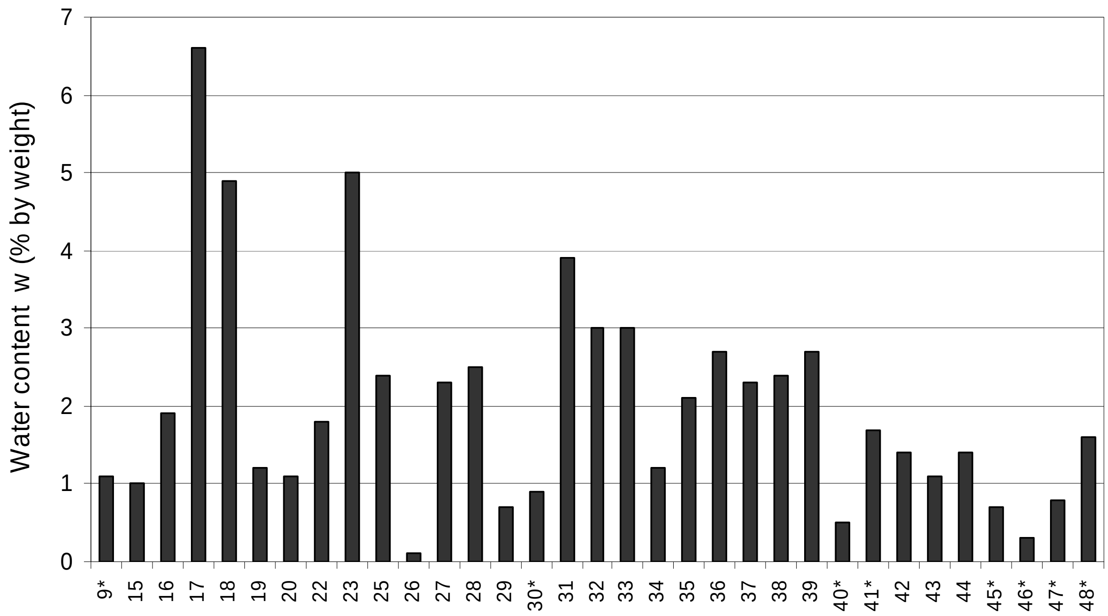


Fig. 3 Water content of the 33 individual specimens taken from the fill/slab -interface beneath the slab-on-ground structures.

5 Microbe growth in fill layers

The total fungal growth (cfu/g) detected in the 49 specimens is presented in Fig. 4. In 59 % of the specimens some fungal growth was detected. Indicator fungus species found in the samples were: *Acremonium*, *Aspergillus versicolor*, *Trichoderma*, *Exophiala* and *Rhodorula*, starting from the most frequently detected species.

The occurrence of fungi seems to have some dependency on the age of the building. In the oldest structures built in the 30's or earlier, the fungal growth was minimal, practically non-existent. In the structures completed in the 60's, 70's and 80's, the growth was detected occasionally. In the newest buildings, completed in the 90's or later, fungal growth was very common and the number of detected colonies high (Fig. 4). This result was surprising, as the general conditions, fill temperature and moisture content, were favourable for microbe growth in all of the surveyed buildings, regardless of the age of the structure. This indicates that initially extensive fungal growth in the fill layer of any new building dies slowly out, as the nutriments required for fungal growth depleted at the relatively sheltered location beneath a slab and the spores left in the layer lose their ability to germinate in the long run. Therefore the specimens from the oldest buildings are almost clean and those from the newest are highly contaminated.

Fig. 5 presents the analysis results concerning the bacteria contamination of the same specimens. Bacterial growth was very common in the soil fill layers, as it was detected in 97 % of the specimens (Fig. 5). Some of the concentrations were extremely high, over 10.000,000 cfu/g (Fig. 5). Bacteria were detected in all age groups of the buildings, including the oldest structures.

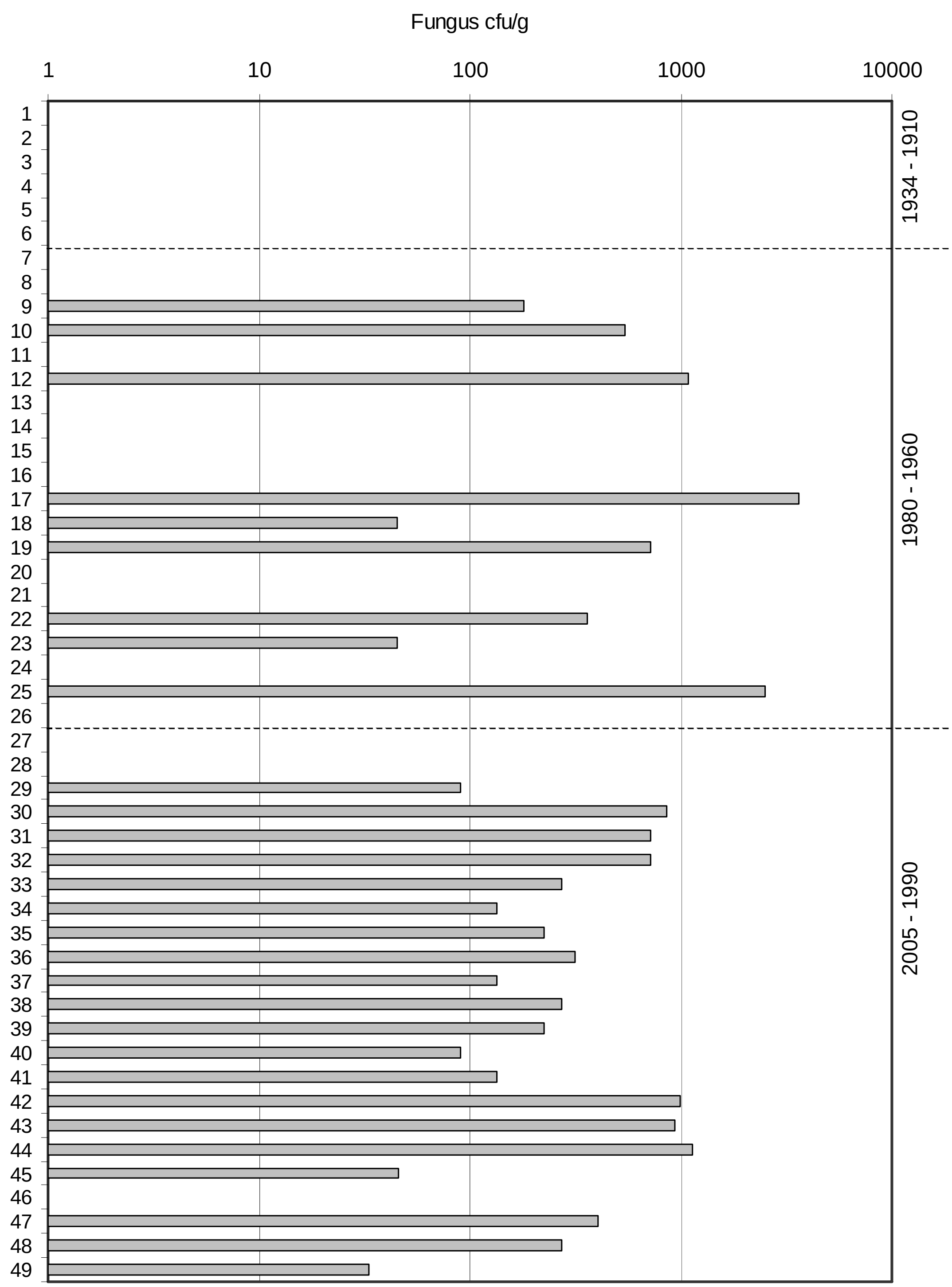


Fig. 4 Detected fungal growth in the 49 specimens.

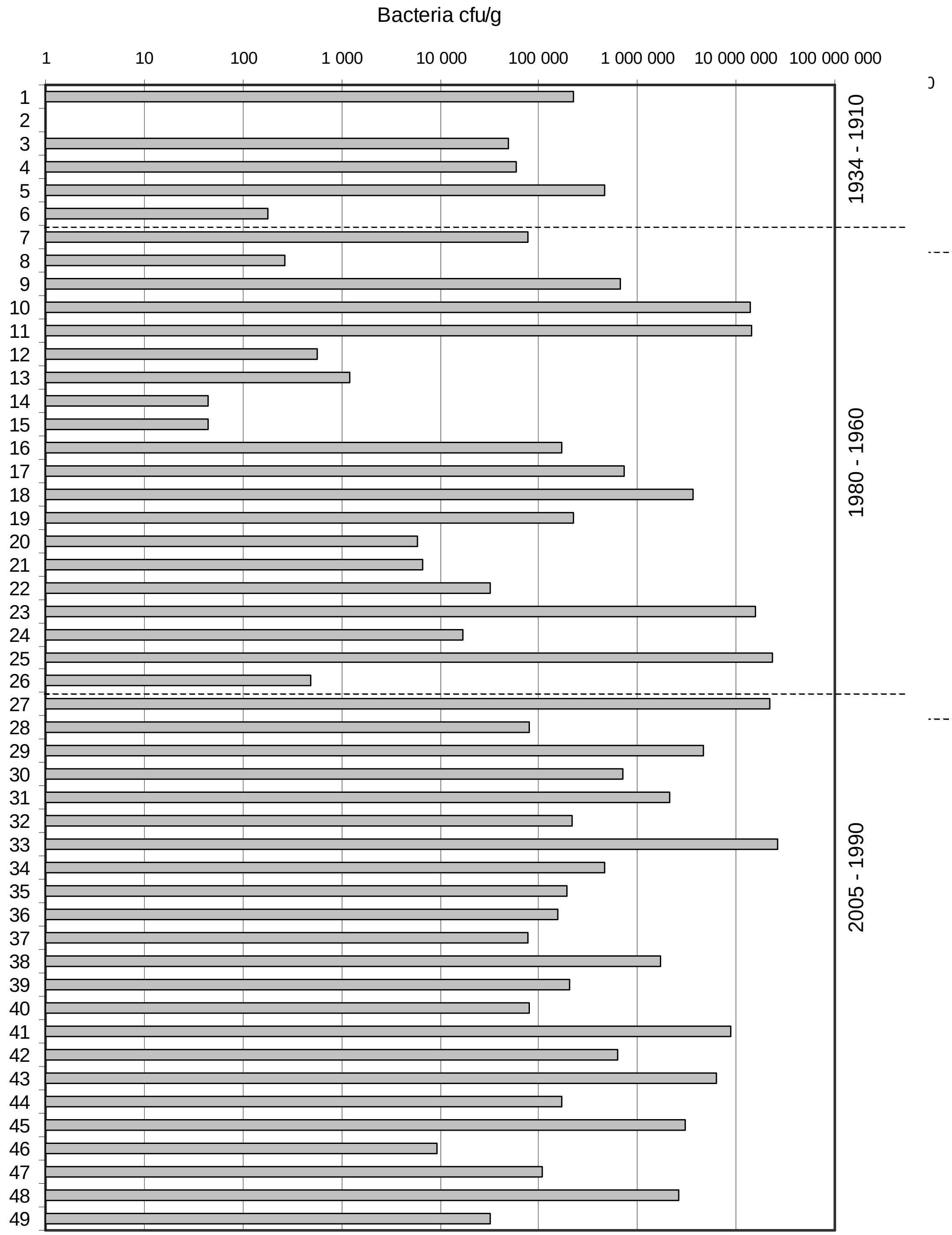


Fig. 5 Detected bacteria growth in the 49 field samples.

In addition, three reference samples of the typical raw material (gravel) of the fill layers were analysed. The specimens were taken from three different sand pits in Southern Finland, at the average depth of one meter from the surface of the already sieved soil fill material, ready to transport for using drainage layer beneath new slab-on-ground structure. The average values of the detected microbe content of these specimens are presented in Table 1.

Comparison between moisture content and detached fungal growth of the surveyed soil fill layers has been presented on Fig. 6. There were no direct dependency between the detected fungal growth and the measured water content of the sample. Fungal growth was detached both samples which moisture content was in hygroscopic or capillary range. In all samples the relative humidity was high and favourable for fungal growth.

Table 1 The average microbe content of the 49 test samples and the three reference samples from the performed quantitative analyses.

cfu/g	Actinomycea	Other bacteria	Indicator fungus	Other fungal
Average (49 specimens)	61 776	3 245 879	61	350
Maximum	1 484 000	25 960 000	540	36 44
Reference tests, average (3 specimens)	45 158	1 233 439	248	1554

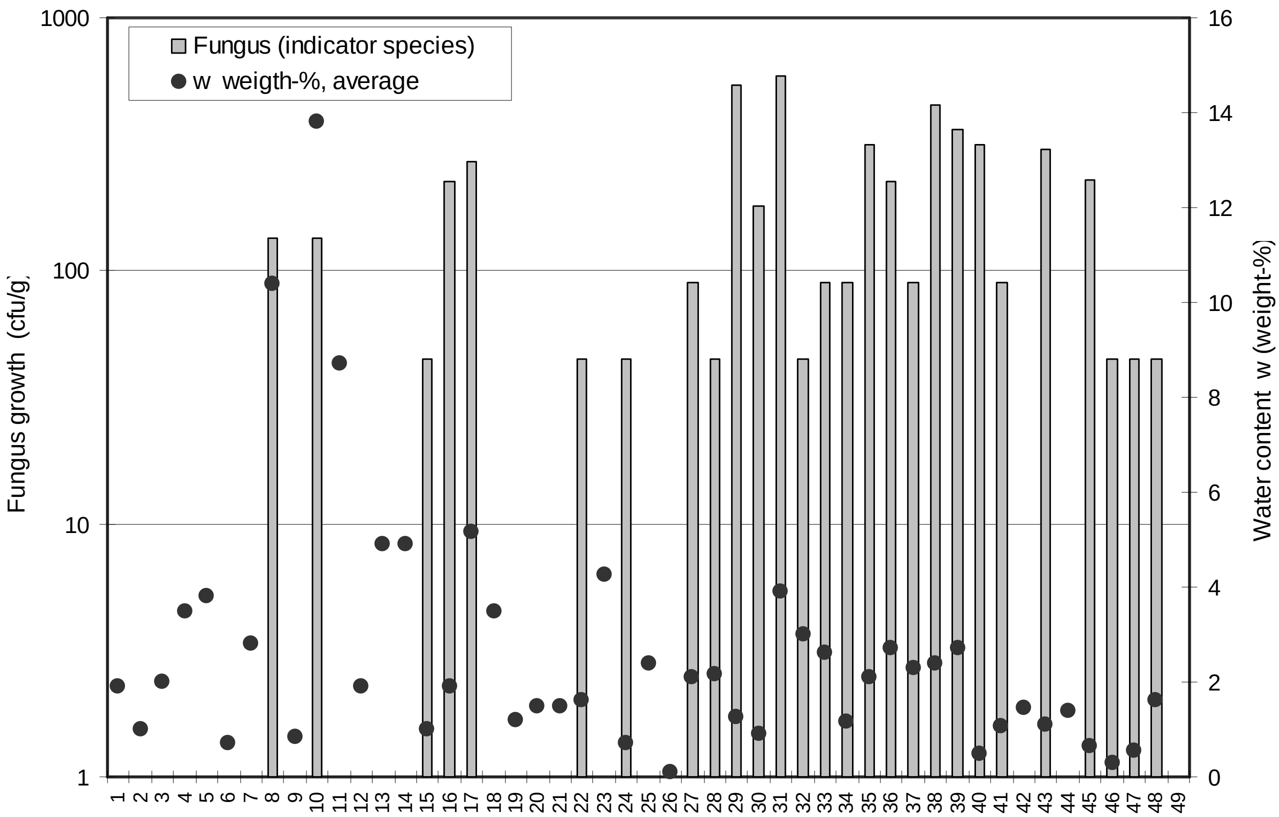


Fig. 6 Comparison between the detected fungal growth and the water content of the surveyed fill layers.

6 Conclusions

According to the results of field test series performed in this and previous studies [1,2], the average conditions, temperature and moisture contents, of the fill layers beneath a slab-on-ground of any heated building are favourable for microbe growth. The relative humidity of the fill soil layer is high, RH ≈ 100 %, throughout the year.

High relative humidity of the soil fill layer is not a sign of an un-functional drainage or capillary break layer, but a natural boundary condition for a slab structure adjacent to the moist subsoil.

Due to the favourable conditions, microbe growth is very common in soil fill layers. Fungal or bacterial growth in general was detected in 98 % of the test specimens taken from beneath the ground slabs of heated buildings. The indicator species, either fungal or bacterial, were detected in 79 % of the specimens. Also, the average concentration of the detected microbes was high.

Detection of microbes in the fill layer is not a sign of moisture damage to the ground slab, and should not be misinterpreted as such. Microbe growth in the fill layer beneath a heated building must be considered as an existing boundary condition for any new or old ground floor structure.

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