

A field study of the distribution of degraded flooring components in a concrete floor

C Engström ^{2,4*}, T Hall ^{2,5}, A Sjöberg ^{1,3}

¹Div. of Building Materials, Lund University.

²Dept. of Building Materials, Chalmers University of Technology.

³Fuktdimensionering Sweden AB.

⁴NCC Teknik.

⁵White arkitekter AB.

ABSTRACT

Among Swedish practitioners it is suspected that SBS-symptoms can be caused by emissions from degraded flooring adhesive on damp concrete (RH >85%). These emissions are dominated by 2-ethyl-1-hexanol and 1-butanol. As part of a moisture damage investigation of a building, where inhabitants had complained of health-related problems, three rooms with different flooring on the same concrete slab were investigated for signs of degraded flooring adhesive. Concentrations of 15 000 µg/m³ of 1-butanol, 2-ethyl-1-hexanol together with relative humidities of about 88% were found in the concrete pores under the PVC-flooring, at a thickening of the slab. The concentrations of 1-butanol and 2-ethyl-1-hexanol were lower (100-1000 µg/m³), in a room where the PVC-flooring had been removed two months prior to sampling. In a third room where the PVC-flooring had been replaced by wood laminate flooring, concentrations of 1-butanol and 2-ethyl-1-hexanol were down to 100 µg/m³ and the relative humidity was at 68%. The concentrations of 1-butanol and 2-ethyl-1-hexanol under the PVC-flooring indicate that degradation of flooring adhesive with subsequent emissions of VOCs to indoor air had occurred. Thus the removal of part of the PVC-flooring may have increased the rate of degassing and dehydration of the slab. Differences in relative humidity and how long the floor is left exposed to air seem to be factors explaining the difference in VOC-concentrations between different parts of the slab.

INDEX TERMS

Relative humidity, Emissions, Contaminant distribution, Concrete, Adhesive

INTRODUCTION

In Sweden, the number of buildings investigated for moisture damages, believed to have caused SBS have increased since the beginning of the 1980s. The investigators are most often practitioners from the field of construction, building design or renovation. They often work with the hypothesis that health problems could be connected to moisture damaged material. One of the “usual suspects” among these moisture damages is decomposition of polymer flooring systems on damp concrete. Wengholt-Johnsson (1995) investigated the effect of moisture and alkalinity on PVC-flooring in a laboratory environment and she found that elevated levels of relative humidity and alkalinity caused increased VOC-emissions, which were dominated by 1-butanol and 2-ethyl-1-hexanol. Sjöberg (2001) showed that these VOCs are also absorbed into the underlying concrete. VOCs absorbed into the concrete can become a source of “secondary emissions”, especially if the flooring is removed or replaced by a material less tight to diffusion.

Scientific research on possible health effects of exposure to emissions from decomposition

products of polymer flooring is scarce. In a case study Norbäck et al. (2000) concluded that asthma symptoms may be related to increased humidity in concrete floor constructions and to emissions of 2-ethyl-1-hexanol. Tuomainen et al. (2002) found a yearly incidence of asthma about 16 times higher than normal in an office building where 2-ethyl-1-hexanol had been emitted from PVC-flooring on damp concrete. Palomäki et al (2002) found a 14% decrease in sick leave in an office building where linoleum flooring on damp concrete was replaced by an epoxy coating. In common for the few existing case studies on a possible connection between alkaline degraded flooring material and health effects is that no attempt to quantify the degradation damage has been made. It could be argued that there is no standardized method available today to make such quantifications. The purpose of this field study was to explore the possibilities to determine the extent (area, depth and concentrations) of an alkaline degraded flooring damage

METHODS

Sampling

The sampling sites are shown in figure 1. Three sites were at the thickening of the slab (the haunch) close to the outer wall. Two sites were situated closer to the inside wall of the room, where the concrete slab was thinner. A hand held hammer drill (Hilti TE72) equipped with a large bit designed to take out cores of 90 mm in diameter was used (no watercooling). Concrete pieces from each site were removed with a hammer and chisel from the depths of 0-1, 2-3 and 4-5 cm and were immediately put in the analysis glass bottles. Later, a fraction of the concrete pieces of each sample was transferred to glass test tubes for RH-measurements. The test tubes were sealed with rubber lids and later fitted with probes for relative humidity measurements (PROTIMETER, DP 989 M, probe 6900).

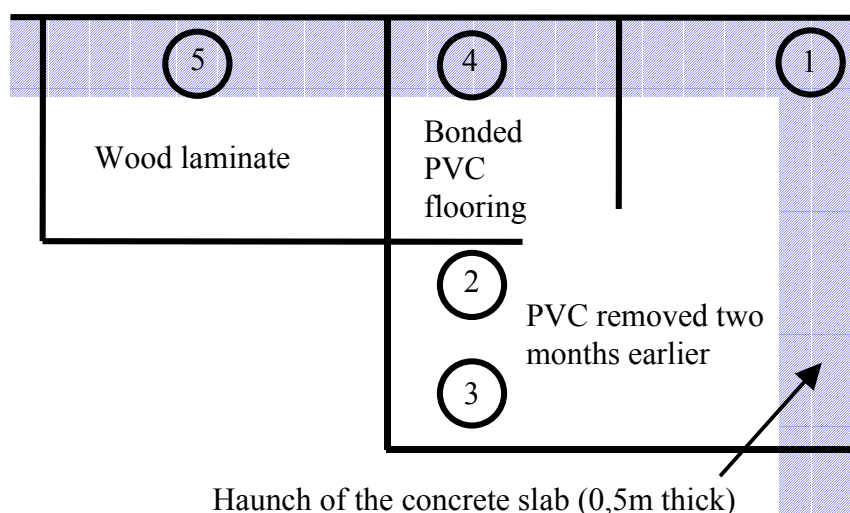


Figure 1: Blueprint showing the sampling sites in the three rooms. The dashed area shows the thickening of the slab – the haunch.

Analysis

The concrete pieces were stored at room temperature in the bottles that they had been put into at the sampling site. After a period of one week, equilibrium of 1-butanol and 2-ethyl-1-hexanol between the concrete pores and the air of the bottles was assumed to have been reached. The air of the sample bottles was assumed to reach the same concentrations of 1-

buthanol and 2-ethyl-1-hexanol as the air of the concrete pores, in analogy with the theory behind relative humidity measurements. The lids of the sample bottles were equipped with an outlet at the end of a bendable steel tube. By using a syringe, 20 ml of air from the bottle was sucked from the bottle through a TENAX tube. The TENAX tube was then placed in an injector oven and desorbed into a gas chromatograph for analysis of 1-butanol and 2-ethyl-1-hexanol. The method is further described in Sjöberg 2001 and Sjöberg 2003 (Healthy Buildings "New device to measure VOC in concrete").

Calculations

In an attempt to estimate how long it would take to air out the contaminants from the most contaminated site, a mass flow calculation for 1-butanol was carried out on site 4. Site 4 was the most contaminated site. The calculations were made with a forward finite difference method based on Ficks 1st law. The method is further described in Sjöberg (2001). As a basis for the calculations it was assumed that the concentrations of 1-butanol at site 1 and 4 had been identical before the PVC-flooring was removed at site 1 (two months earlier). If the flooring was to be removed at site 4 also, it was assumed that the concentrations at this site would drop to the same concentrations as those measured at site 1, in two months. The calculations were then repeated forward to simulate how the concentrations would continue to drop for another 4 months.

RESULTS

Building factors

The building in question is a one storey building built in 1974, situated a few kilometres inland on a field in a valley, close to the west coast of Sweden. It has mechanical exhaust and mechanical inlet air. The foundation of the building consists of a 250 mm concrete slab with 0.52 m thick haunches. Ocular inspection of the holes drilled in the concrete slab, showed that there was a 40 mm layer of screed on top of the concrete slab. Beneath the slab was a plastic diffusion barrier on shingle (coarse gravel), but no thermal insulation. A drainage pipe was beside the haunch, 2-3 dm below surface level (the pipe is to be replaced with a new pipe placed below the haunch). This study focused on three rooms in one end of the building (fig 1), because these rooms were to have their floorings renovated. In the first room a PVC-carpet had been replaced by a wood laminate flooring a few years ago. In the second room the PVC-flooring was still in place, and in the third room the PVC flooring had been removed two months prior to the time of sampling.

Measurements of relative humidity, 1-butanol and 2-ethyl-1-hexanol in concrete

The results from the measurements of relative humidity are shown in figure 2. Sites 1, 4 and 5 were at the thickening of the slab (the haunch). At site 4 where the PVC-flooring was still in place, the relative humidity was the same at all three depths. At the same haunch in the next room (see figure 1) the flooring had been removed, leaving the slab exposed to the

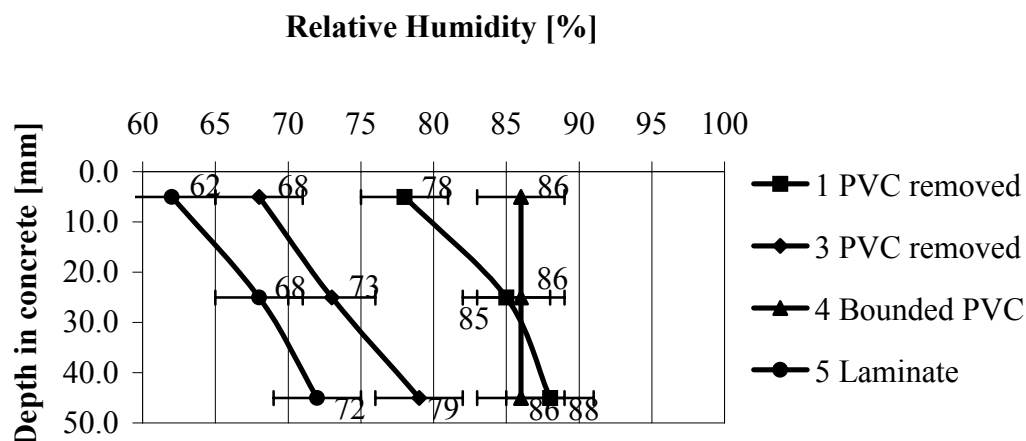


Figure 2: Measurements of relative humidity in the upper 50 mm of the slab

indoor air. Here the relative humidity increased with increasing depth. The relative humidity at site 5 was considerably lower than at sites 1 and 4 although all three sites were positioned along the same haunch. At site 3, where the slab was about 250 mm thick and the PVC-flooring had been removed, the relative humidity was down to about 70%. No relative humidity measurement was carried out at site 2, where only a surface sample had been taken

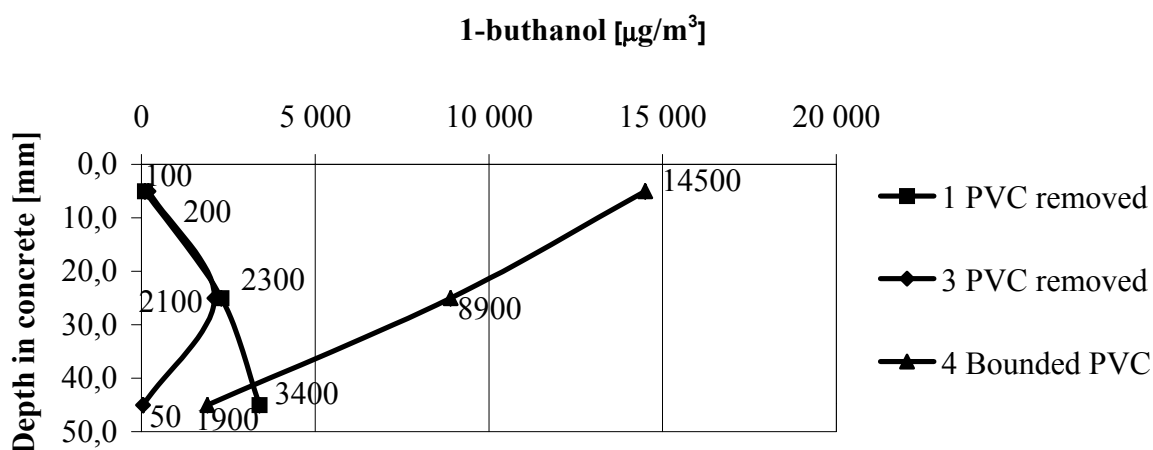


Figure 3: Free concentrations of 1-buthanol measured in the pores of the concrete slab.

The 1-buthanol and 2-ethyl-1-hexanol measurements displayed in figure 3 and 4 show that the concentrations of both VOCs were considerably higher where the PVC-flooring was still in place and the slab was thick. At site 1 along the haunch, where the concrete had been exposed to air, the amounts of 1-buthanol and 2-ethylhexanol were much lower close to the slab surface, than they were deeper down in the slab. At sites 3 and 4, where the PVC-flooring had been removed two months prior to sampling, the concentrations were very low close to the surface and higher at a of 20-30 mm.

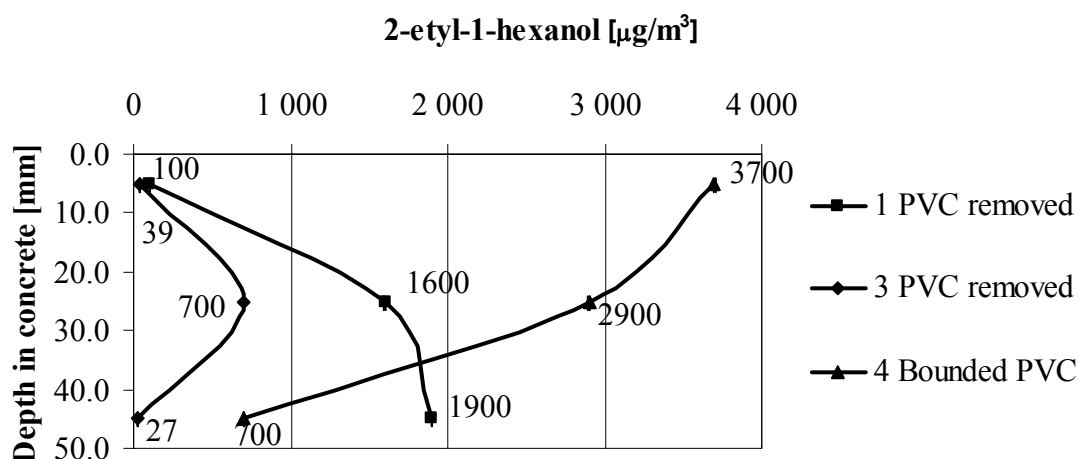


Figure 4: Measured free concentrations of 2-ethyl-1-hexanol in the pores of the concrete slab.

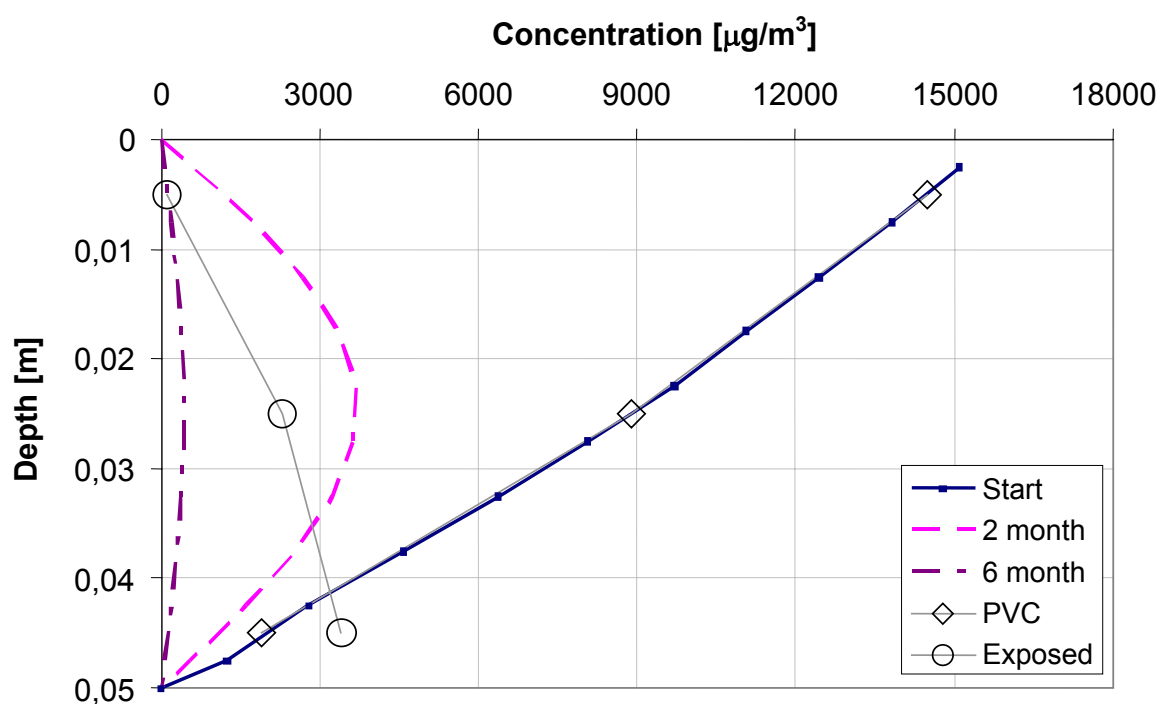


Figure 5: Estimated future concentrations of 1-buthanol at site 4 if the PVC-flooring would have been removed at the day of sampling. “Exposed” shows measured concentration at site 4, where the flooring had been removed. “PVC” shows measured concentrations at site 4, where the flooring was still in place.

Figure 5 shows an estimation of how the site 4 concentrations of 1-buthanol would look after 2 and 6 months of exposure to air.

DISCUSSION

The fact that some of the samples contained 2-ethylhexanol and 1-buthanol indicated that the flooring adhesive had been exposed to alkaline dampness which caused alkaline hydrolysis of the flooring adhesive. The alkaline degradation of the adhesive caused emissions of 2-ethyl-1-hexanol and 1-buthanol. As most of the 2-ethylhexanol and 1-buthanol were found in the haunch, it seems that the biggest source of excess moisture, causing increased alkaline hydrolysis, was water from the mixing of the concrete. The water from the 0,52 m thick

haunch probably did not have time to dry before the PVC-flooring was installed. At the haunch under the wood-laminate flooring (site 5), the low VOC content and the low relative humidity indicate that the flooring is permeable to VOC and moisture. The even depth distribution of moisture at this site also indicates that there is no moisture entering from below the haunch. At sites 1 and 3 the removal of the PVC-flooring had probably allowed the concentrations of 1-butanol and 2-ethyl-1-hexanol at the 0-1 cm level to drop. However the higher concentrations at the 2-3 and 4-5 cm levels indicates that the concentrations had been higher before the PVC was removed. Compared to measurements by Sjöberg (2001) and Engström (2002) the amounts of degradation products measured in this study can be regarded as "common" for an alkaline moisture damaged flooring. It should be noted however, that there is almost no other comparable data in the scientific literature, which means that no definitive conclusions can yet be made. The result shown in figure 5 of the attempt simulate the airing out of 1-butanol indicates that it would probably take several months to air out most of the contaminants.

CONCLUSION AND IMPLICATIONS

The results of this study show that the distribution of emissions from degraded flooring material may vary considerably between different parts of a concrete floor. One measurement is not sufficient to establish the status of a moisture-damaged flooring. A good way to find secondary emissions is to study the moisture distribution in the concrete slab. Gaining an understanding of where to look for secondary emissions is useful for practitioners in their moisture damage investigations and for the scientist trying to study the possible connection between damp floorings and health.

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