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Deterioration of PVC floor covering due alkaline moisture

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Deterioration of PVC floor covering due alkaline moisture

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Abstract. Concrete as alkaline (pH ~12,5) and moist material can cause deterioration of polyvinyl chloride (PVC) floor coverings and adhesives through alkaline hydrolysis. Attempts to prevent alkaline hydrolysis have mainly been made by installing PVC floor coverings above 'dry-enough' concrete or by using self-levelling low-alkali (pH ~11…11,5) screeds between concrete and floor coverings. In this study, screed, adhesive and PVC floor covering combinations have been varied by using different floor covering conditions in laboratory test series. VOC emissions have been analysed from flooring material samples (Bulk-VOC). The test samples have been measured for two to three years after installing floor covering. According to the results, a 5 mm layer of low-alkali screed (pH less than 11,5) will effectively protect PVC flooring against alkaline hydrolysis. It could also be concluded that the pH level immediately under floor covering has a better correlation with VOC emission than the RH of concrete in the moment of installing the floor covering.

1. Introduction

Among the indoor pollutants causing poor indoor air quality (IAQ), volatile organic compounds (VOCs) have hazardous effects on human health and well-being. VOCs are emitted by many indoor sources such as flooring.

Main cause of VOC emissions due deterioration of PVC flooring and some commonly used flooring adhesives (such as acrylate-based copolymer) is hydrolysis of esters [1]. The efficiency of the reaction depends on the moisture content or relative humidity (RH), temperature and pH. There is potential for VOC emissions due the degradation processes of PVC flooring glued to concrete slabs, as the moist and high pH of the concrete slab (pH ~12.5) provide perfect conditions for hydrolysis. Attempts to prevent this phenomenon have been made by installing floor coverings on top of 'dry-enough' concrete or by using a low-alkali layer (screed) between the concrete and the floor covering. Some degradation has been observed at pH 11 in a PVC flooring [2] and it has been concluded that the critical pH value for degradation of flooring adhesives is between 11 and 13 pH [3], defined by floor and adhesive samples in contact with liquid of pH 11 and 13. The studies considering low-alkali layer have been mainly performed in Sweden at 1990's and 2000's. The PVC flooring materials has been significantly changed, plasticizers have been replaced and the emissions have been decreased due legislation, such as restrictions for use of the phthalates. Therefore, in recent years, commonly used phthalate plasticizers in PVC have been replaced with others, such as diisonyl cyclohexane-1.2-dicarboxylate (DINCH) [4].

The reaction products of DINCH are typically long-chained alcohol isomers (C8…C10) [5], while the reaction product of 2-ethyl-1-hexanol (2-EH) was from hydrolysis of diethylhexylphthalate (DEHP) [1].

The objective of this research was to investigate deterioration processes of currently commonly used PVC floorings. Screed, adhesive and PVC floor covering combinations have been varied using different floor covering conditions (RH of the concrete) in full-scale thickness laboratory test series.

2. Laboratory test series

Test samples, cast in steel boxes, consisted a 20 mm layer of EPS (expanded polystyrene) at the bottom and an 80 mm layer of concrete on top. The test samples were stored under constant conditions: T = +21 °C and RH = 50%, until the RH of the concrete at the equivalent depth reached the agreed level. The maximum RH level of the interface layer after installing floor covering equals the RH (RH_{crit}) under the so-called equivalent depth before installation, based on experience and studies. The RH was measured by handheld Vaisala HMP40 T & RH sensors, through plastic tubes, installed prior to casting. Moisture level of concrete during installing floor covering (RH_{crit} in 32 mm depth from the top) has been varied: RH80%, RH85% and RH93%. The RH85% equals current guideline flooring criteria. Some samples were applied with 5 mm self-levelling screed layer. The pH of screed material or pH of flooring underlay has been varied: gypsum-based screed (pH less than 10), low-alkali screed (pH about 11.5) and cement-based screed or no screed (pH ~12,5). Two different types of adhesives were used: common acryl copolymer dispersion and alkali resistant adhesive. Three floor covering has been varied: two homogenous floor coverings, used in public spaces, one consisted of DINCH plasticizer and another DINP (diisononyl phthalate) plasticizer and one heterogenous floor covering, used in housing rooms, consisted DINCH plasticizer. After flooring the moisture was able to dry out only upwards through flooring. Total 23 different material combination included in laboratory test series.

VOC emissions were analyzed from material samples and surface emission samples. Material samples or Bulk-VOC samples were collected from 40 x 40 mm^2 material sample, including floor covering and some adhesive and screed, into a Tenax TA tube using a Micro-Chamber/Thermal Extractor (Micro-Chamber, µCTE) and then the emissions were analyzed using a thermal desorption–gas chromatography–mass spectrometry (TD-GC-MSD) [6].

The pH of the concrete and the screed was defined from material samples using a method introduced in [7]. A sample was drilled from the concrete or the screed, 1 to 2 mm upper layer in contact with the floor covering, and the 0.5 ± 0.01 g drill dust was mixed with 5 ± 0.2 g ion purified water. After the solid matter settled, the pH of the liquid was measured using a pH electrode. The samples for pH analysis have been collected at the same time as the flooring material samples. The detached floor material sample was prepared for VOC analysis and pH samples were drilled from the underlay.

3. Results

Total 101 VOC analysis from the flooring material samples have been made, two to five analysis from each test sample. The first samples have been collected about three months after installing floor covering and last samples 2.5 or three years after. In 58% of taken samples the floor covering was homogenous with DINCH plasticizer, in 31% heterogenous DINCH and in 11% the floor covering was homogenous with DINP plasticizer. The most common VOC emission compounds were 2-ethyl-1-hexanol (2-EH), long-chained alcohol isomers (C9-C10) and 1-Butanol, as expected. In samples were the floor covering was homogenous with DINCH plasticizer, the average TVOC (total-VOC) concentration was 1082 $\mu g/m^3$ g (maximum 9400 $\mu g/m^3$ g), in samples of heterogenous DINCH 536 $\mu g/m^3$ g (maximum 1300 $\mu g/m^3$ g) and in samples of heterogenous DINP 4470 $\mu g/m^3$ g (maximum 15 000 $\mu g/m^3$ g), correspondingly. The dominant compound in samples were the floor covering was homogenous with DINCH plasticizer was 2-EH (43%), in samples of heterogenous DINCH 1-Butanol (80%) and in samples of homogenous DINP 2-EH (38%). The water-vapor resistance of heterogenous flooring is lower and therefore even a smaller amount of deterioration products could affect IAQ. The C9-C10 alcohol concentration levels are still increasing in samples of homogenous flooring.

TVOC concentrations of all 101 VOC analysis compared with moisture content, RH%, during floor covering and pH of the flooring underlay have been presented in Figures 1 and 2. There are no clear correlation between RH% during floor covering and TVOC, but 63% of the samples which TVOC concentration was above 1000 μg/m^3 g, were covered in RH=93%. Correspondingly, if the TVOC concentration exceeded 1000 μg/m^3 g, in 89% of the samples the pH of flooring underlay was above 11.5. If the TVOC concentration was above 2000 μg/m^3 g, the pH of flooring underlay was above 12 in all samples. Similar correlation could be also seen between 2-EH or C9-C10 alcohol concentration and pH of the flooring underlay. Also analysis of surface emission samples (FLEC-VOC, not presented here) conformed these findings.

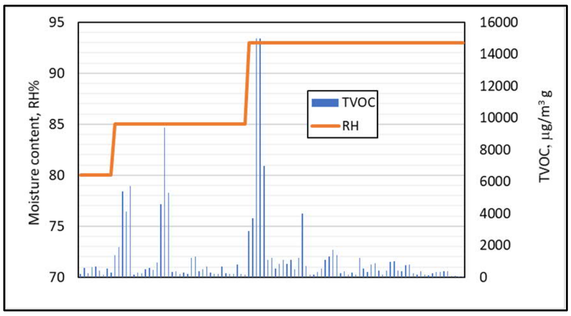

Figure 1. Correlation between TVOC and RH.

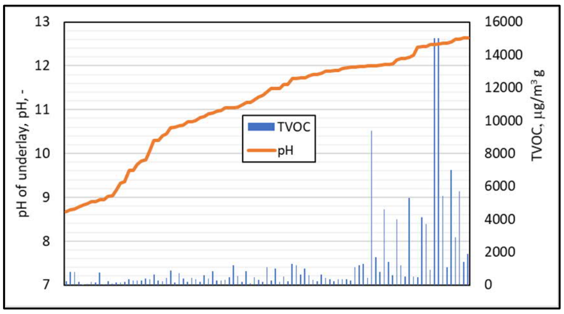

Figure 2. Correlation between TVOC and pH.

4. Conclusions

If pH of the floor underlay is less than 11.5, it will effectively protect deterioration of PVC flooring due alkaline hydrolysis, according to laboratory test series. It could be arranged by using low-alkali screed layer between concrete slab and flooring. This previously discovered finding is also valid for new flooring materials with new type of plasticizers.

Also it could be concluded that the pH level immediately under floor covering has a better correlation with VOC emission than the RH of concrete in the moment of installing the floor covering. Therefore both moisture content (RH% of the concrete at the equivalent depth) and pH of the surface above the flooring should be a criteria for installing PVC flooring.

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