Effects of coating a drying Calcium Sulphate Floor on the relative humidity of the Structure

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Abstract. Cast structures must be allowed to dry sufficiently before they can be covered with impermeable coatings. During a commissioned study on the drying rate of calcium sulphate screed cast floor, it was observed that the measured relative humidity of the structure increased significantly after a vinyl flooring was glued to the surface of the structure. The cause for the phenomenon could not be determined based on the carried-out test arrangements. Therefore, a follow-up study with identical test structures was conducted to isolate the cause of the increase in measured relative humidity after coating. Tests confirmed that the effect was caused by the water contained in the adhesive. The adhesive was initially dosed by applying it with a trowel with specified notching as instructed. In the follow-up study, weighing the applied amount of adhesive revealed that the instructed amount was exceeded significantly. Due to the shape of the material's equilibrium moisture content curve, even a small increase in moisture content significantly increases the structure's relative humidity. Therefore, dosing instructions of applied adhesive must be followed precisely, as overdosing can potentially lead to moisture damages in related structures.

1. Introduction

Evaluating the humidity of cast structures is a critical part of a construction stage. Drying times have a significant impact on building schedules and prolonged drying will delay the installation work. On the other hand, an adequate drying of casted structures before installation of impermeable coating layers must be ensured. Premature sealing of structure surfaces can result in moisture damages in joint moisture sensitive structures, which may lead to mold growth and indoor air problems. This may cause health problems for the users of the building in addition to reconstruction costs. In addition to humidity levels of structures, material and product specific instructions must be followed when installing a coating layer. Therefore, a reliable measuring method is required to monitor the moisture of cast structures. [1]

During a commissioned study on the drying rate of calcium sulphate floor, it was observed that the measured relative humidity of the structure increased significantly as a result of coating. The chosen coating method was a vinyl flooring glued to the surface of the structure. As an aftereffect of coating the moisture content in entrapped air in material pores ascended tens of percentage units although the structure was confirmed to be dry before coating. The phenomenon was not limited only on the surface section of the structure, but it was also measurably noticed at the underside of the slab. The coating was installed according to the adhesive's user instructions and the development of the structure's relative humidity was monitored with continuous measurements. [2]

The test structures of calcium sulphate screed cast floors were cast in 500 mm * 500 mm sized molds with thickness of 50 mm or 80 mm. The molds were built in such a way that drying of the test structures was limited to only one direction. Some of the test structures were heated to different temperatures with floor heating cables. During the drying tests, the effect of coating the test structures with a vinyl flooring was examined. The study observed a strong and inconsistent increase in relative humidity measurement values in all test structures after the vinyl flooring was installed. Figure 1 shows relative humidity measurement results from measuring depth of 35 mm of an 80 mm thick test structure, which was gradually heated to a temperature of 50 °C. The figure shows that the measured values of relative humidity of the test structure increased by approximately 40 % units RH after coating.

The cause for the observed increase in relative humidity after coating could not be determined based on the carried-out test arrangements. Therefore, a follow-up study was conducted. The previous test arrangements were repeated with identical structural details to limit the variations in the experiment to different coating methods. Different coating methods were used to study the effect of different components related to coating a calcium sulphate screed cast floor with the chosen adhesive and vinyl flooring. [3]

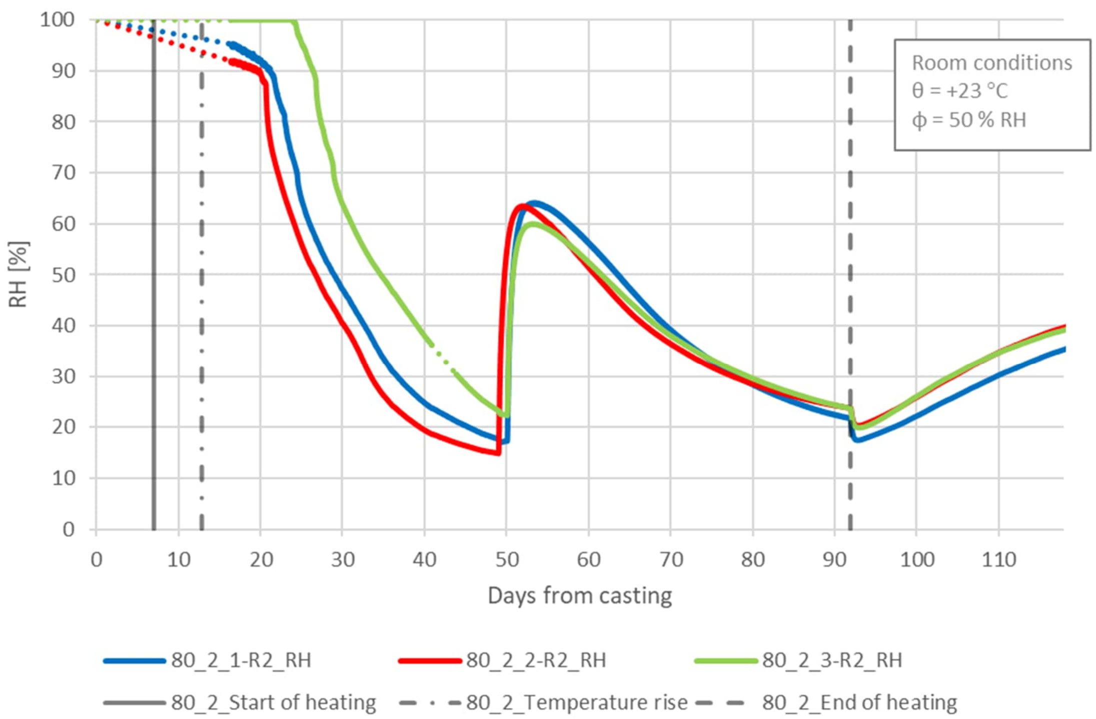

Figure 1. Effect of coating on relative humidity measurements during previous study. Depth of measurement 35 mm. Test structure was gradually heated to 50 °C. Measured RH increased almost 50 percentage points after coatings near day 50 and gradually decreased over 40 days.

2. Test arrangements

2.1. Test structures and measurements

The follow-up study focused on investigating the increase in relative humidity measurement values observed after coating and finding out the cause of the phenomenon. The test structures were designed identical to the previous study for direct comparison and to minimize unnecessary uncertainty factors. Three sets of 500 mm * 500 mm * 80 mm sized test structures were cast for the coating tests. Test series 1 and 2 were gradually heated with heating cables to a temperature of 35 °C, which was mentioned by the screed product manufacturer to be a common practice in the field when floor heating is utilized for drying the structure. The test structures of test series 3 were unheated and used for the second coating test round. Details of test series 3 were determined after the results of the first coating tests on heated test structures. Drawings and dimensions of casting molds are shown in Figure 2.

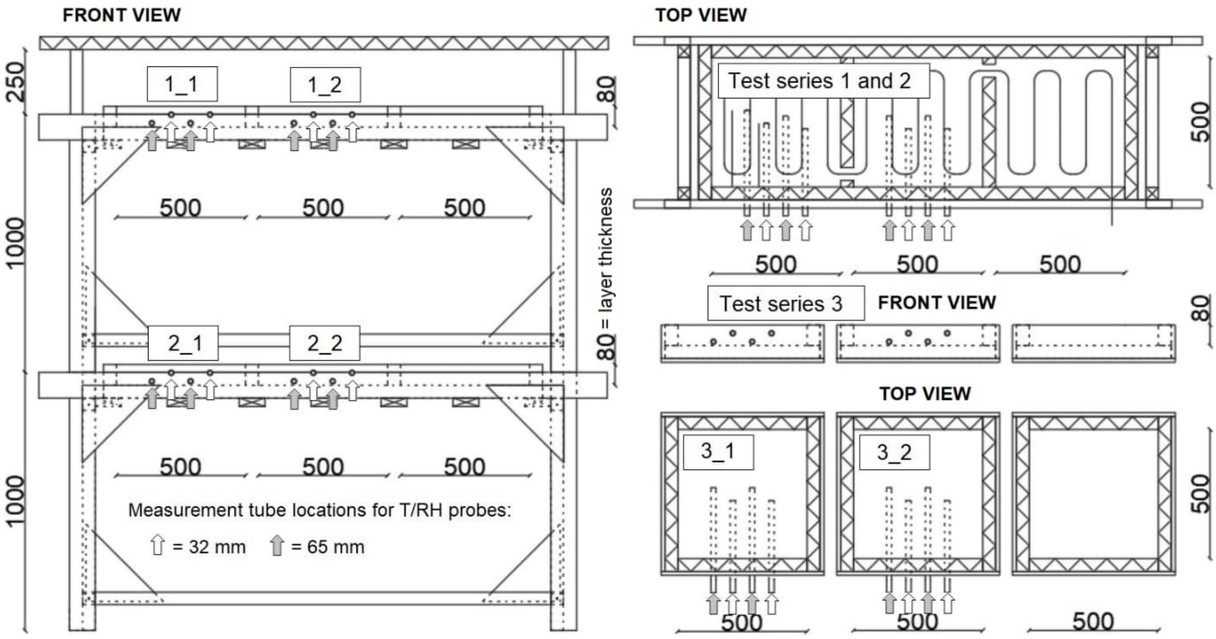

Figure 2. Drawings and dimensions of the casting molds. Measuring tubes in two measurement depths are marked with arrows. Dimensions of all the test structures are 500 mm * 500 mm * 80 mm.

The measurements used RH probes from two different manufacturers, and they are referred as Probe_R and Probe_V in the following graphs. Probe_R were used in the previous research. Probe_V is a relative humidity probe that is commonly used in the field and was included for the follow-up study alongside Probe_R as additional verification to eliminate possible device specific errors that could mislead the results. After casting the test structures, relative humidity measurements were started with a maximum settling time of 60 minutes in the measuring tubes installed in the casting mold. These measurements were continued regularly until the measured relative humidity of all test structures had fallen below 90 % RH 60 days after casting. Continuous measurements were then started and continued until target humidity was reached, after which the heating was stopped, and the coating tests were carried out.

After coating, the moisture development of the test structures was monitored with continuous measurements. The probes were sealed into the measuring tubes as in the continuous measurements before coating. The probes were allowed to settle in the measuring tubes for a few days before coating, so that the initial settling of the probe would not complicate the analysis of the measurement results.

2.2. Coating methods of test structures

The four test structures of the two heated test series were coated in different ways. Test structure 1_1 was coated with a glass sheet, which was sealed from the edges with vapor barrier compound and vapor barrier tape. Test structure 1_2 was coated with vinyl flooring, which was sealed from the edges with vapor barrier compound and vapor barrier tape. Test structure 2_1 was coated with vinyl flooring, which was glued to the surface of the test structure with the adhesive used in the previous study. Test structure 2_2 was coated by applying the same amount of adhesive as in test structure 2_1 to the surface of the test structure and the surface was left uncovered.

The coating methods for the two unheated test structures were chosen after analyzing the results of the first coating tests. Test structure 3_1 was coated with a glass sheet, which was glued to the surface of the test structure. Test structure 3_2 was coated with a glass sheet with the amount of water contained in the adhesive first sprayed under the glass sheet. Glass sheets of both test structures were also sealed from the edges with vapor barrier tape.

In the adhesive's product instructions, the spreading capacity is given as 4–6 m^2/l, which is equal to 0.17–0.25 l/m^2, and a density of 1.1 kg/l. Thus, the recommended amount of adhesive to be used for a 500 mm * 500 mm test structure is 46–69 g. When coating test structures 2_1 and 2_2, the adhesive was applied to the surface of the test structures using a trowel with instructed notching. A subsequent weighing revealed that the amount of the applied adhesive exceeded the instructed values significantly. An estimated average of 170 g of adhesive was consumed per test structure. In the previous study, the average consumption of adhesive was reported as 0.44 l/m^2, which is equal to 121 g per test structure, which also clearly exceeds the instructed amount. The excessive adhesive consumption is likely due to uneven grinding result caused by the applied tool. The water content of the adhesive is 35%. Thus, 170 g of adhesive contains 60 g of water, and these amounts were weighted and applied under the glass sheets of tests of structures 3_1 and 3_2.

After the two planned rounds of coating tests, it was deemed necessary to carry out an additional coating test round. The third round of coating tests compared the minimum and maximum amount of adhesive corresponding to the given spread capacity to observe the result when complying the given spread capacity. The taped coatings of test series 1 were removed to release the test structures for further coating tests. Test structure 1_1 was coated with vinyl flooring using 46 g of adhesive. Test structure 1_2 was coated with vinyl flooring using 69 g of adhesive. Pictures of coated test structures are shown in Figure 3.

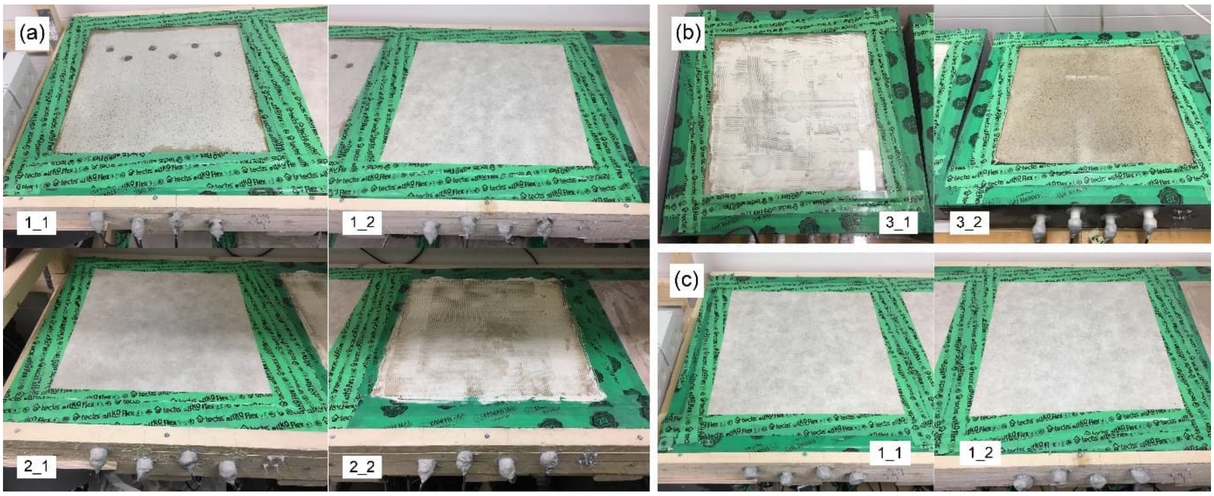

Figure 3. Coated test structures. (a) 1st coating tests for heated test sets 1 and 2. (b) 2nd coating tests for unheated test set 3. (c) 3rd coating tests for reused test set 1.

3. Results

3.1. 1st coating tests

The test structure 1_1 was coated by taping a glass sheet to the surface of the test structure. The coating does not appear to have a significant impact on measurement values and RH probes of both manufacturers settled at measured values of 50 % RH approximately. The clear glass sheet allows observation of the surface of the test structure under the coating layer, but no noticeable condensation of moisture or anything other worthy of attention was observed. The glass sheet also excludes possible effects of any chemical compounds emitted from the vinyl flooring which could potentially interfere the RH sensors. The measurement results of the first coating tests are shown in Figure 4.

The test structure 1_2 was coated by taping a vinyl flooring to the surface of the test structure. As with the glass sheet of test structure 1_1, the vinyl flooring does not appear to have a significant effect on the measurement values either and the measurement results between the test structures are very similar. The difference from the previous study in this method of coating is elimination of floor adhesive's possible effect.

The test structure 2_1 was coated by gluing the vinyl flooring to the surface of the test structure as in the previous study. RH probes of both manufacturers reacted strongly to the floor adhesive and the effect of the coating on RH measurements is very similar to the previous study. The vinyl flooring was removed at 21 days after the coating. This was done to observe how the moisture values change as a result compared to the adhesive coating of test structure 2_2.

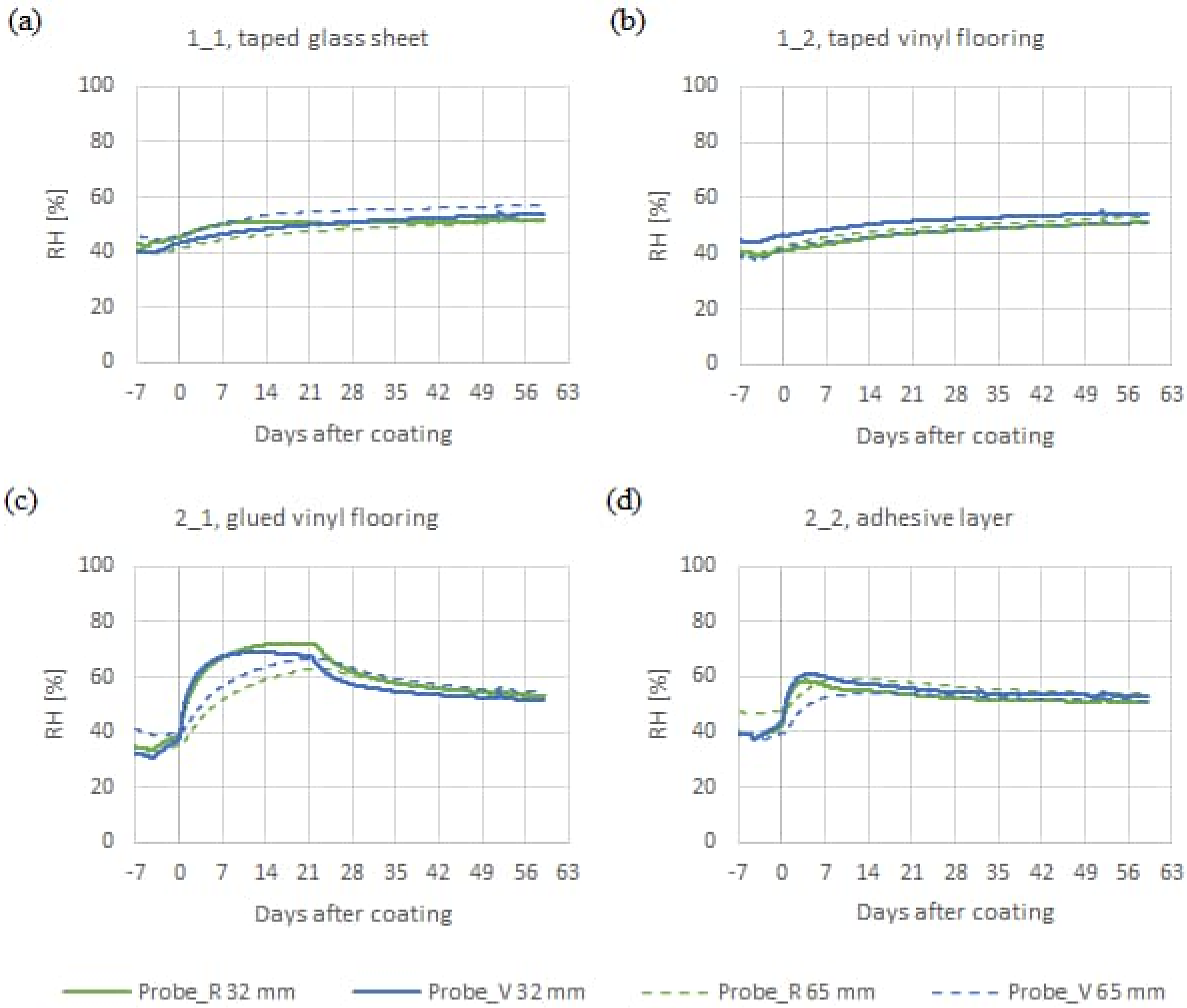

Figure 4. Measurement results of the 1st coating tests. (a) Test structure 1_1: glass sheet taped to the surface of the structure. (b) Test structure 1_2: vinyl flooring taped to the surface of the structure. (c) Test structure 2_1: vinyl flooring (removed 21 days after coating) glued to the surface of the structure. (d) Test structure 2_2: adhesive layer applied to the surface of the structure. The coating was applied at the zero point of the time axis (day 0).

Test structure 2_2 was coated by applying a layer of adhesive to the surface of the test structure using trowel with instructed notching, as was done with test structure 2_1, but the surface of the adhesive is left exposed. RH probes of both manufacturers clearly react to the adhesive, but not as strongly as in the case of test structure 2_1, where the adhesive was sealed under vinyl flooring. The measured humidity values eventually settle to approximately the same readings as the test structures mentioned above.

3.2. 2nd coating tests

According to the first coating tests, the adhesive was the component causing the measured moisture values to rise in the previous study. To further investigate the factor behind the phenomenon, it was decided to compare the adhesive with its contained water amount. The unheated structures of test series 3 were both coated with a glass sheet. On test structure 3_1 the glass sheet was glued with the equal amount of adhesive used on test series 2. On test structure 3_2 the amount of water contained in the adhesive was sprayed on surface of the test structure before taping the glass sheet on top. The measurement results of the second coating tests are shown in Figure 5.

In test structure 3_1, RH probes of both manufacturers react strongly to the adhesive and the effect of coating is very similar to the glued vinyl flooring with test structure 2_1, but the rise is even stronger, and the RH values seem exaggerated with Probe_R. The measuring device showed similar behavior in the initial phase of the study when measuring high moisture concentrations.

In test structure 3_2, both Probe_R and Probe_V reacted slightly stronger to pure water than in test structure 3_1, where water was bound to the adhesive. The peak of the measured relative humidity curve of Probe_V is slightly higher than in test structure 3_1. Probe_R readings continue to increase up to 100 % RH and the same is repeated when the probe is changed to another calibrated probe during the first five weeks. Only after the probe is replaced for second time the measured humidity settles below 100 % RH reading and the measured values start to decrease similarly to Probe_V.

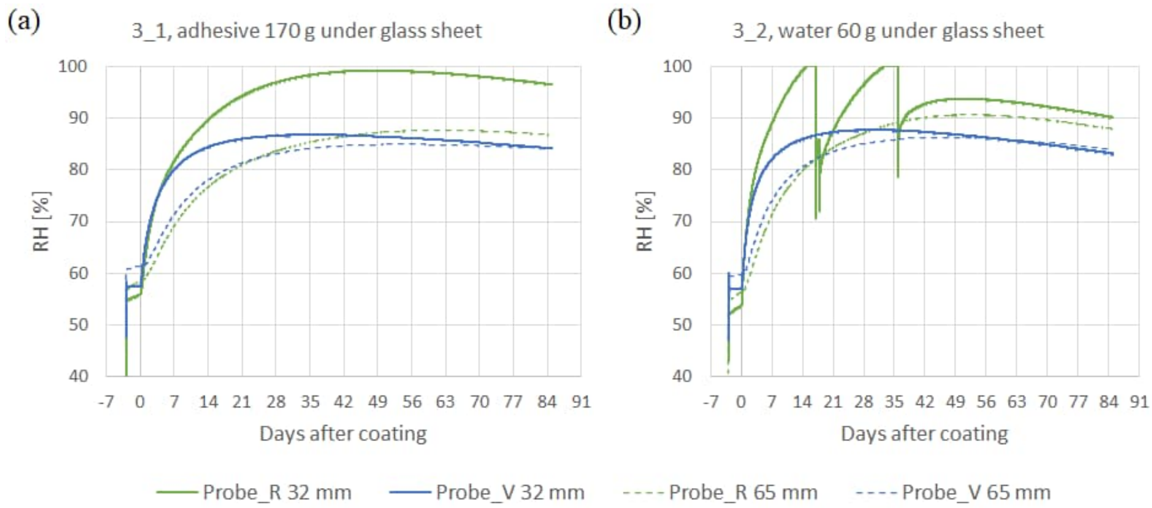

Figure 5. Measurement results of the 2nd coating tests. (a) Test structure 3_1: glass sheet glued to the surface of the test structure. (b) Test structure 3_2: glass sheet taped on top of the sprayed amount of water contained in the adhesive in 3_1.

3.3. 3rd coating tests

In the third coating test, the test structure 1_1 was coated by gluing a vinyl flooring to the surface of the test structure by applying the instructed minimum amount of adhesive for the structures surface area. The minimum instructed amount of adhesive caused the humidity readings to rise, but the increase is much more moderate, and the humidity does not rise to readings that are critical for coating materials. Behavior of both Probe_R and Probe_V seem reliable in these humidity values. They settle at the same values and the decline after peak values of the humidity readings is almost identical.

Test structure 1_2 was coated by gluing a vinyl flooring to the surface of the test structure by applying the instructed maximum amount of adhesive for the structure's surface area. The increase in the measured relative humidity values caused by the maximum instructed amount of adhesive is slightly greater but still moderate, and the humidity does not reach critical levels for coating materials. Behavior of both Probe_R and Probe_V seem consistent in this case as well. The measurement results of the third coating test are shown in Figure 6.

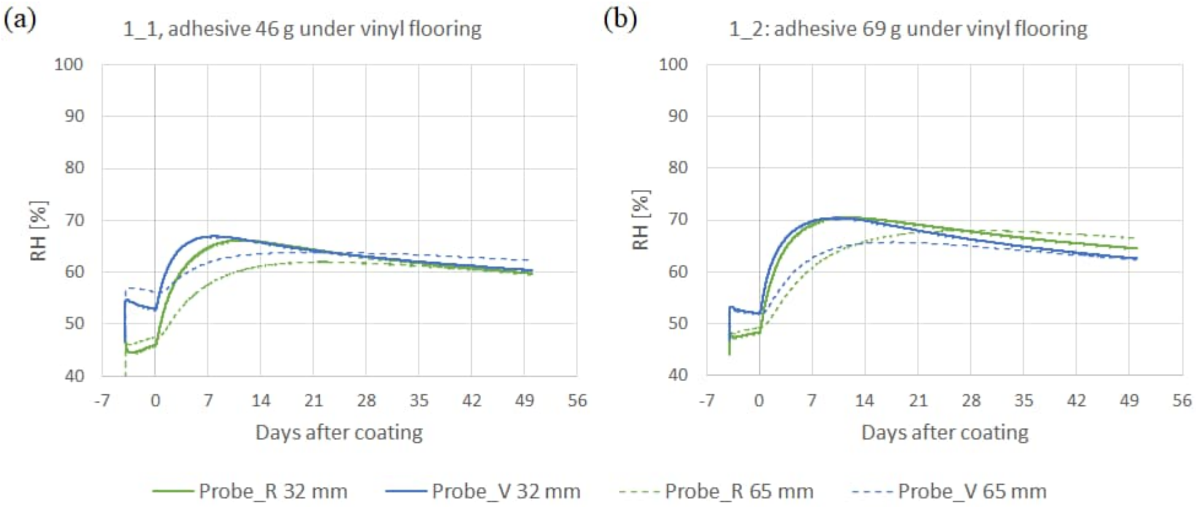

Figure 6. Measurement results of the 3rd coating tests. (a) Test structure 1_1: vinyl flooring glued to the surface of the structure with the instructed minimum amount of adhesive. (b) Test structure 1_2: vinyl flooring glued to the surface of the structure with the instructed maximum amount of adhesive.

4. Discussion

The follow-up study showed that the phenomenon observed in the original study is due to the water contained in the floor adhesive. The added amount of water is not significant in quantity, but due to hysteresis and the shape of the equilibrium moisture content curve of calcium sulphate, a small increase in moisture content sharply increases relative humidity of the material as shown in Figure 7. The equilibrium moisture content curve of the used floor screed product has not been determined, but the equilibrium moisture curve of calcium sulphate obtained from source [4] can be considered a sufficiently accurate generalization in terms of the phenomenon.

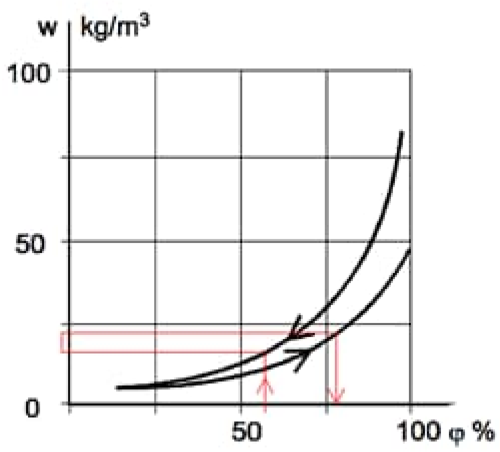

Figure 7. Equilibrium moisture content curve of calcium sulphate (1240 kg/m^3) and the effect of increase in moisture content on the material's relative humidity as a result of hysteresis. Image modified from source [4].

In the previous study, the adhesive was dosed using a trowel with specified notching as instructed. This was also the method used in the first coating tests of this study. Based on the weighing made afterwards, it was found that a considerable amount of adhesive had been consumed compared to the recommended consumption calculated from the instructed spreading capacity. Excessive adhesive consumption is presumably due to unevenness of the surface caused by the small grinding tool used for grinding the small-surfaced test structures. In later coating tests, the amount of adhesive was determined by weighing.

5. Conclusion

The reasons for the increase in the relative humidity values measured after coating can be named as water contained in the floor adhesive and the excessive dosage of the adhesive, hysteresis and the shape of calcium sulphate's equilibrium moisture content curve and measuring device specific measurement error. The shape of calcium sulphate's equilibrium moisture content curve and hysteresis cause a relatively small addition of water to significantly raise relative humidity of the material's pore air. Overdosage of adhesive may raise relative humidity of a structure to a critical level for coating materials, which can result in moisture damage and indoor air problems. Therefore, product specific instructions of adhesive dosage should be followed strictly when coating calcium sulfate screed cast floors.

References

[1] Merikallio T 2009 *Evaluation of adequate drying of a concrete floor during construction process* (Helsinki: Helsinki University of Technology) p 136
[2] Haaranen A 2017 *Drying of Calcium Sulphate Floor Screed Cast on Insulation Layer* (Tampere: Tampere University) p 174
[3] Raunima T 2020 *Behavior of Capacitive Humidity Sensors in Monitoring the Drying of Concrete Walls and Calcium Sulphate Floors* (Tampere: Tampere University) p 105
[4] Nevander L E and Elmarsson B 2006 *Fukthandbok* (Stockholm: AB Svensk Byggtjänst och författarna) p 538