TKB – FQA

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TKB

Questions & Answers

concerning the KRL Method* of Screed Moisture Determination

*KRL = korrespondierende relative Luftfeuchte / corresponding relative humidity

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Preliminary note

This catalogue of questions & answers on the KRL method was compiled by the Technical Committee Construction Adhesives (TKB) based on questions from the trade and from experts. For each question there is at least one answer. If two are given, the first is short (highlighted in green) and summarizes the gist whereas the second goes more in-depth and explains details that may require a higher level of technical knowledge.

Question 1
Why does the TKB recommend sampling analogous to the CM method and not the drill-hole method used, for example, in Scandinavia?

The Scandinavian drill hole method is, in the context of only 50 mm thick screeds, very sensitive to deviations from the specified measuring depth and therefore prone to errors, especially since the nominal screed thickness often does not correspond to the actual thickness. Moreover, the construction site needs to be visited twice, because a waiting time of 24 hours must be observed between drilling the hole and performing the in-situ measurement at the drill-hole. Due to these practical problems, TKB in the end decided to adopt the sampling process of the CM method and to recommend measurements on the chiselled-out material.

The Scandinavian drill-hole method was developed for concrete floors of 10 cm thickness or more. Most concrete floors in Scandinavia dry on one side only as they are installed on a vapor barrier. When measuring in drill-holes of different depths, it is easy to see how the concrete slowly dries from the top down. This also means that, for long periods of time, any krLF* value can be measured, depending on the drill-hole depth. Since also in Scandinavia this method is used to determine the readiness for flooring installation, the idea was to select a drill-hole depth corresponding to the krLF value that would be obtained after covering the concrete with a flooring material. This depth, also called "equivalent depth" according to Göran Hedenblad, corresponds to 40% of the concrete thickness (this applies to concrete of 100 mm thickness drying from one side). For thicker concrete slabs, concretes with different water/cement ratios and one- or two-sided drying, this value varies. The exact value can be taken from tables (Hedenblad 1996, Kanare 2008).

Transferred to a German screed of 5 cm average thickness, this would mean a drill-hole depth of 20 mm. However, since the drying curve has a very steep gradient, even small changes in the drill-hole depth will have a relatively strong effect on the measured value. After drilling the hole and inserting the plastic liner, it is necessary to wait 24 hours until the state of equilibrium moisture is restored and a meaningful measurement can be carried out.

Hedenblad, 1996: Hedenblad, G., Drying of Construction Water in Concrete – Drying Times and Moisture Measurement, Stockholm, Byggforskningradet, 1997

Kanare, 2008: Kanare, H. M., Concrete Floors and Moisture, EB119, Portland Cement Association, Skokie, Illinois, and National Ready Mixed Concrete Association, Silver Spring, Maryland, USA, 2008

Question 2
Is the KRL method "state of the art"?

In Germany, the technology clause "state-of-the-art" applies to the KRL method. This means that it is the latest available method that is also scientifically recognized. However, it still needs to prove itself in practice.

Recognized rules of technology (source Wikipedia, 2018-10-06, translation of the German original):

"The (generally) recognized rules of technology are technology clauses for the design and the execution of structural installations or technical objects. They do not need to be codified, but they usually are.

It can be assumed that the generally accepted rules of technology are known to a technician who has been trained according to the current state of knowledge and that they have proven themselves on the basis of continued practical experience.

The recognized rules of technology must be distinguished from the "state of the art" (European also: "best available techniques") and from the "state of science and technology". These terms each relate to the latest available methods, which, however, have neither established nor proven themselves to date."

Generally recognized rules of technology (OLG Hamm, judgement of 18.04.1996 – 17 U 112/95) (summary):

The "generally recognized rules of technology" are understood to be the rules applicable to the design and construction of buildings and building works which are accepted in science as theoretically sound and which have established and proven themselves in practical construction work.

In accordance with the above definitions, the KRL method can be classified as "state of the art" (see TKB Reports 1 to 5).

https://www.klebstoffe.com/die-welt-des-klebens/informationen/publikationen/merkblaetter/bauklebstoffe-verlegewerkstoffe/berichte.html

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Question 3
Is the KRL method also suitable for screeds with screed additives (fast-drying or accelerated screeds)?

Yes. According to the current state of knowledge, the KRL method is the best and safest method for these screeds to determine their readiness for flooring installation.

For accelerated screeds, increased limit values are often stipulated for the CM measurement. Usually, there is no conclusive reason for this.

In many cases, screed additives have the effect that good working properties can be achieved for the screed even with a reduced amount of gauging water. The reduced amount of water means that less moisture needs to be released to the ambient air to achieve a moisture level (in wt-% or CM-%) at which the screed can be assumed to be ready for flooring installation. Reduced moisture also implies a shorter waiting time until the screed is ready to receive flooring.

However, the sorption isotherm of a screed depends on its actual composition, including the water/cement ratio. Usually, the following rule applies: The lower the w/c ratio, the lower also the position of the sorption isotherm. From this follows that a defined CM value, which indicates the readiness to receive flooring, corresponds to different relative humidity values. Relative humidity (RH) indicates, independent of the position of the sorption isotherm and thus independent of the screed composition, whether further moisture needs to be released until a state of equilibrium is reached. If the position of the sorption isotherm is unknown, the CM value, contrary to the KRL value, does not provide reliable information about the readiness for flooring installation.

This makes the KRL method the safest method for assessing the screed moisture level, especially for screeds containing additives.

Question 4
How accurate are the measuring devices used for the KRL method? Is device accuracy relevant?

Inaccuracy of the measuring devices recommended by the TKB for measuring air humidity is in the range of 1 to 2% in relation to the measured value. This device inaccuracy, which in this case also corresponds to the calibration inaccuracy, is smaller than the method inaccuracy.

At 80% RH, this means a range of +/- 0.8 to 1.6% RH (see TKB Report 3).

In comparison, calibration inaccuracy of the CM method is 5%. At 2.0 CM-%, this corresponds to a range of +/- 0.1 CM-%. This means that also for the CM method device inaccuracy is smaller than the method inaccuracy.

Device inaccuracy: This is the inaccuracy of the device with its sensors.

Calibration inaccuracy: This is the inaccuracy with which a device can be calibrated. At best, it is equal to the device inaccuracy, but can be worse.

Method inaccuracy: This covers all errors that may be involved in a measuring method. In addition to the device and calibration inaccuracies, there are also inaccuracies resulting from the handling of the device and from the entire measurement procedure.

Question 5
What is the method (in)accuracy of the KRL method?

Concerning the readiness for flooring installation, the inaccuracy of the KRL method is approx. +/-5% krLF (corresponding relative humidity). This means: At a measured value of 75% krLF, the "true value" is in the range of 70-80% krLF. This approximately corresponds to the inaccuracy of the CM method.

When determining the method inaccuracy, deviations in the measurement execution are added to deviations in the device performance. This includes the processes of sampling and weighing as well as the measurement procedure (shaking technique, measurement times). The results obtained by the TKB from a round robin test carried out for the KRL method show a comparable inaccuracy for both the KRL and the CM method (see TKB Report 5).

Question 6
What does a measuring device suitable for the KRL method cost?

The price of TKB-recommended devices is in the range of 500 to 1000 EUR. A list of these devices can be found in TKB Report 3.

Devices suitable for the KRL method need to meet certain requirements. In particular, they must

1. produce sufficiently accurate results over the relevant moisture range
2. be largely free from drift
3. be capable of calibration and
4. be robust (insensitive to dust) and suitable for use on construction sites.

The Hamburg University of Technology (TUHH) checked the devices for their suitability and prepared an evaluation. This forms the basis for the TKB recommendation list.

Question 7
How reliable is the result of a KRL measurement for assessing the screed moisture level resp. the readiness for flooring installation?

In practice, the corresponding relative humidity (krLF) is the parameter of greatest significance for assessing the readiness of a floor or screed to receive flooring.

The following parameters are required for a complete evaluation of the screed moisture level:

1. corresponding relative humidity (krLF)
2. absolute moisture content (Darr value)
3. sorption isotherms
4. diffusion coefficients

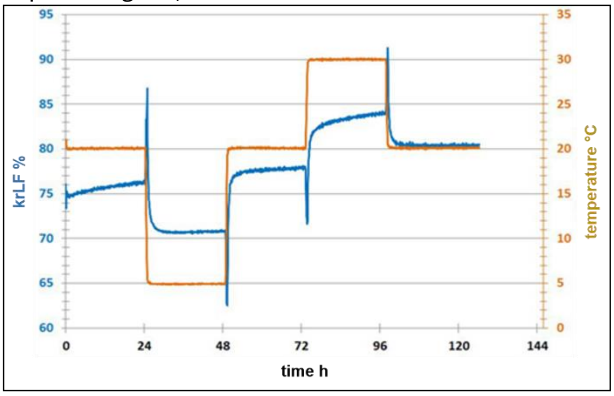
Measuring all these parameters is not feasible under practical conditions on site. Therefore one of these parameters is usually deemed to be sufficient. The krLF value indicates how high the air humidity is and whether moisture will diffuse from the screed into adjacent building materials. Whether this is liable to cause damage must be inferred from the context. However, below certain limit values damage can definitely be excluded.

Question 8
Which temperature influences must be considered in the KRL measurement?

When performing a KRL measurement, 2 types of temperature influence need to be considered:

- Temperature changes that occur while performing the measurement.
  These occur, for example, when the material to be tested is taken from a cool floor, but the subsequent measurement is carried out in a warmer location, e.g. on a warm, sunlit window sill. Such temperature changes are not permissible since they may significantly falsify the result. The sample must maintain its original temperature. It is therefore best to perform the measurement directly next to the sampling point.
- Temperature changes that occur when the measurement is performed at different site temperatures.
  In principle, the result of the KRL measurement, i.e. the krLF value, is temperature-dependent. However, the deviations are small. Lower temperatures result in slightly lower krLF values. Take for example a normal temperature of 20 °C: If this deviates by 1°C, the krLF value will change by 0.4% absolute. The typical temperature range for flooring installation is 15 to 25 °C. Based on this range, the total temperature error is max. +/- 2% krLF. This corresponds to the inaccuracy of the measuring device.

The two processes can be illustrated with the help of the following measurement result (taken from TKB Report 4, fig. 12):



Please note: The sample used for this test (and others -> see TKB Report 4) had not yet reached its equilibrium moisture. The moisture value there-fore rises in the course of the measurement.

The blue curve with the scale on the left indicates the corresponding relative humidity krLF measured for the sample. The orange curve with the scale on the right shows the temperature at which the KRL sample was stored.

Time is plotted on the X-axis (in black at the bottom of the graph). You can see how the humidity changes every 24 hours when the sample is taken into another room with a different temperature. If the new room is cooler, air humidity will first rise sharply. The reason is that the absolute humidity remains more or less the same whereas the absolute saturation humidity drops sharply. This causes the relative air humidity to rise.

Please note that this can also lead to condensation. A glance at the diagram "Water vapor pressure at different air humidities" shows that this was very probably the case here (at 20 °C and 75% RH the dew point temperature is approx. 5 °C lower at approx. 15 °C).

It then takes about 2 hours until the temperature inside the sample is back to equilibrium. After that, a krLF value reduced by approx. 5% is displayed. The following temperature changes can be explained in the same way. Please note that the temperature changes observed in this case are very large. Even under unfavourable conditions it should, however, be possible to ensure that the samples are only exposed to small temperature changes while performing the on-site measurement. If in doubt, simply extend the waiting time.

Question 9
Can there be a problem if the temperature during KRL determination deviates from the temperature during flooring installation?

In other words: If you perform the KRL measurement at a relatively low temperature (e.g. 5 or 15 °C) and then install the floor covering at a higher temperature (e.g. 25 °C), is the measurement result valid and can it be used for assessing the screed's readiness to receive flooring?

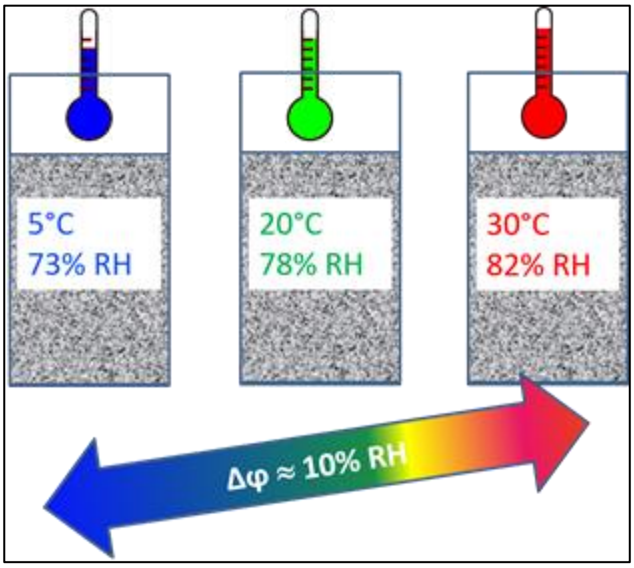
In principle, the TKB recommends a measurement temperature between 15 and 25 °C. In this range, the influence of the KRL method's temperature dependency is negligible. Readiness for flooring can then be assessed without a correction factor.

If, however, the measurement temperature is below 15 °C, the value can be calculated as follows:

For every degree C deviation from standard temperature 20 °C, the measured value must be corrected by 0.4% krLF.

Example:

- Measured humidity value:
  80% krLF at 5 °C
- Correction based on standard 20 °C:
  (20 – 5) °C * 0.4% krLF/°C = 6% krLF
- Corrected value:
  80% krLF + 6% krLF = 86% krLF

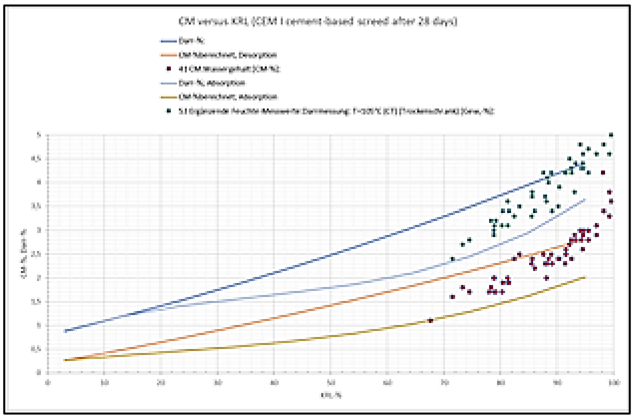


(see TKB Report 4).

Question 10
Is there a simple conversion from krLF percent to CM percent and vice versa?

No, there is no simple conversion.

Between krLF and CM values there is no functional but a relational connection[1]. This means that a range of krLF values can be assigned to a CM value. Vice versa a range of CM values can be assigned to a krLF value. The relationship is determined by the different, material-dependent sorption isotherms (absorption, desorption and scanning isotherms). This is shown by the sorption graph for the respective screed type. The graph below shows the sorption data of a CEM I cement-based screed after 28 days, including both Darr and CM values. The additional data points come from the the KRL round robin test.



[1] For a detailed explanation please refer, for example, to: https://de.wikipedia.org/wiki/Relation_(Mathematik)#Relationen_und_Funktionen

Question 11
The moisture value indicating readiness to receive flooring is material-specific both with the CM and the Darr method. Why does this not apply to the KRL method?

When using the CM or Darr method, the sample's absolute amount of moisture is determined through processes of chemical or thermal drying. However, to assess the readiness for flooring installation it is of primary importance to know whether, in what quantity and at what speed partial amounts of this moisture will diffuse into adjacent building materials. This will vary from material to material. For this reason, it is necessary to define material-specific limit values for the readiness to receive flooring when using the CM or Darr method of moisture determination.

By contrast, the KRL method determines the so-called activity of the moisture diffusing from the material and eventually reaching the state of equilibrium moisture. This is done by a direct measurement of the krLF value.

A physical quantity can be called material-specific if it is directly related to the properties of a material. Example: Compare a cube of wood with one made of concrete. Both cubes may have the same mass: 1 kg. When measuring the edge length of both cubes, you will find that it is 11.9 cm for the wood and 7.5 cm for the concrete cube. The values are different, because density is material-dependent: Concrete has a higher density than wood, so the edge length of the cube is smaller. We now store the two cubes side by side in a room of constant temperature. The next day, we measure the temperature of both cubes and of the room air. The result: We always measure the same temperature regardless of the material (wood, concrete, room air). The temperature is thus independent of material and mass. This also applies to the krLF value: it is independent of the material. If you store different materials in a room of constant humidity and wait until equilibrium is reached, you will measure the same corresponding humidity for all materials, which is equal to the relative humidity of the room air. Even when halving the sample size, the measured humidity will still remain the same.

Whether or not the screed moisture will diffuse into an adjacent building component depends on whether there is an activity difference (in good approximation this is equal to the concentration or partial pressure difference) between the building components.

Absolute water content of different substances at 75 % RH

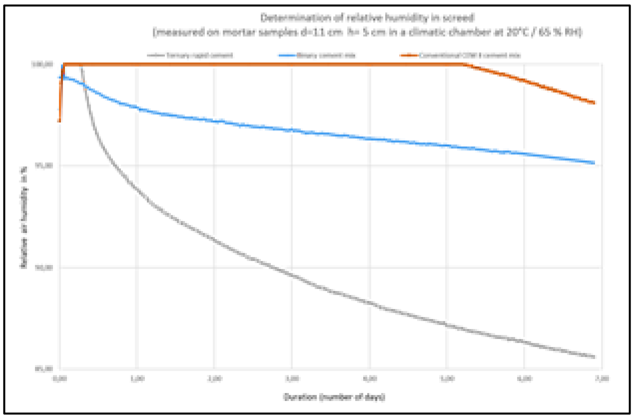
Polystyrene / lightweight levelling mortar / CT / NaCl solution / CAF / MA / beech
Kiln-drying at 105° C; CAF at 40 ° C

In some cases, a material dependence of the krLF value is seen in the fact that the saturation humidity above concentrated salt solutions is different. This is equivalent to the claim that temperature measurements are material-dependent, because different melting points can be determined for different materials. Here, the melting point (which is indeed material-dependent) is confused with the general property "temperature". In the case of the salt solution, the material-dependent, reduced water vapor pressure above the salt solution is confused with the corresponding relative humidity krLF. Just like a melting point is related to a temperature (e.g. ice has a melting point of 0 °C), a saturated salt solution is related to a krLF value (it has a corresponding relative humidity of 75.4%). However, the air pressure needs to be constant.

Question 12
Are there substrates that can be safely covered with flooring even if their krLF value is above the limit of 80%?

In certain cases, especially if the capacity for chemical or crystalline water binding is predominant in a material and physical drying of only secondary importance, a substrate system can be classified as ready to receive flooring even if the krLF value is still increased. With these types of substrates, the formulation ensures that further water is bound in the substrate within a reasonably short time after flooring installation and thus does not cause any damage. This situation occurs, for instance, with ternary fast-setting cement systems (SZ-T). Experience has shown that it makes sense in these cases to define the readiness for flooring installation mainly by means of the setting time (or age), in accordance with the respective manufacturer's recommendations.

The krLF value initially only states whether water vapor can diffuse in a certain direction. Whether damage occurs also depends on how much moisture/water could diffuse (sorption isotherm) and how fast this could happen (diffusion resistance). Also see question 7.



The graph shows the development of relative humidity in 3 screed samples, immediately after pouring the mortar into a mold.

Question 13
What is the difference between "free water" and "damaging moisture"?

These terms are not chemically or physically defined. In fact, there are a variety of forces and interactions between water and other substances that cause water to "stick" or adhere to these substances. It is not possible to draw a conclusion about the readiness for flooring installation based on these supposed properties.

The term "free water" is sometimes used in the context of Darr moisture measurements. Basically, the result of a Darr test is temperature-dependent. The following rule applies: The higher the temperature, the more water is evaporated. From this can be deduced that there is less "free water" present at low temperatures than at high temperatures.

Question 14
Does the result of a KRL measurement depend on whether the measurement is performed in a PE bag or in a CM pressure bottle?

No, the type of test vessel has practically no influence on the result. However, care must be taken both with the PE bag and the pressure bottle that the sensor is placed as close as possible to the test material, preferably on top of it.

Both in a PE bag and in a steel/aluminum bottle, it can be observed that lower values are measured with increasing distance of the sensor from the test material. This is due to the fact that the transport of moisture mainly takes place by slow diffusion.

Question 15
Does the room air humidity influence the result of the KRL measurement?

No, not if the measurement is performed correctly. An effect can only be expected if the bag/ measuring vessel is not tight and if an exchange with the room air takes place.

In this case, however, the result of the measurement is useless.

Question 16
Do I always have to wait about 30 minutes until equilibrium is reached before reading the krLF value or can I read it earlier?

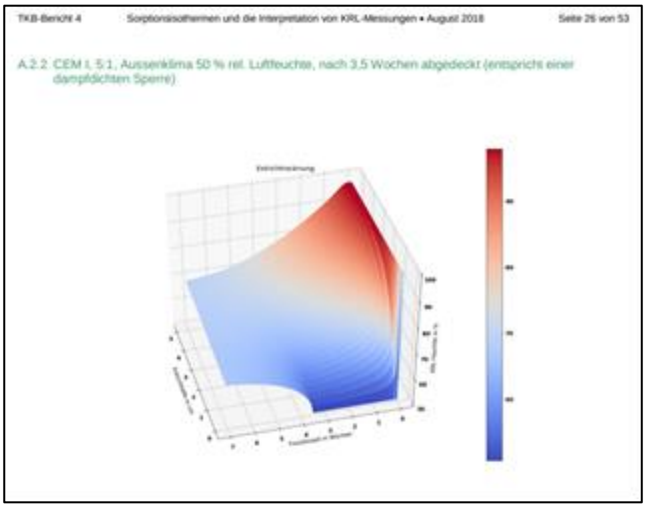
The measurement can be terminated when the displayed value does not change by more than +/- 1% krLF within a period of 3 minutes.

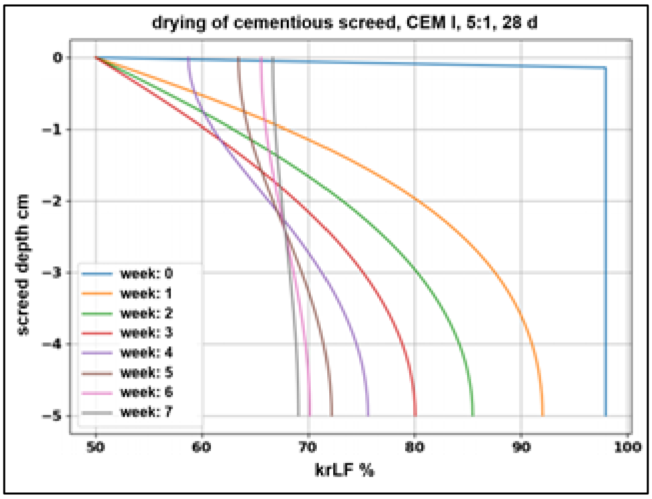
If the measurement is carried out correctly according to the instructions, you will get a value very close to equilibrium after approx. 10 minutes. However, the instructions say: "The corresponding relative humidity can be read off the measuring device when the state of equilibrium is reached. This is considered to be reached when the displayed value does not change significantly within 3 minutes (+/-1% krLF). Depending on the measuring device, this is usually the case after a minimum time of 30 minutes."

Question 17
Why is the sample taken over the entire cross-section of the screed?

Screeds dry "top down", i.e. there is usually a moisture gradient at the time when a moisture measurement is carried out. However, as most floor coverings are effective vapor retarders, the surface of the screed will become damp underneath the floor covering while the underside will slightly dry out. This process of "moisture equalization" comes to a halt when the state of equilibrium is reached. The screed then has the same krLF value over its entire cross-section.

This value is of decisive importance for assessing the readiness for flooring installation. If a crosssection sample is taken for the KRL measurement, its measured value corresponds to the equilibrium value that is reached after the flooring has been installed. Please refer to TKB Report 4 for calculations and illustrations. The following two example diagrams show the development of moisture (drying process) in a screed which was covered with flooring after 3.5 weeks:





Strictly speaking, the calculation shown above applies to a real "vapor barrier", i.e. a floor covering that does not allow the diffusion of water. However, as explained above, many flooring systems are only vapor retarders that allow a small amount of water to pass through. In this case, a constant gradient is produced from the top to the bottom. In almost all cases, however, the difference in the krLF value will be significantly smaller than before.