Relative humidity (RH) in concrete

PROCEEDINGS FROM A NORDIC WORKSHOP
TRONDHEIM – NORWAY, 7. – 8. NOVEMBER 2018
Relative humidity (RH) in concrete

WORKSHOP PROCEEDINGS NO. 13
FROM A
NORDIC WORKSHOP
Trondheim, Norway
7. – 8. November 2018
Preface

This publication contains presentations given at the Nordic workshop on "Relative Humidity in concrete" that was held at SINTEF in Trondheim 7. – 8. November 2018. The workshop was sponsored and organized by SINTEF.

Background and motivation for the workshop

Accurate and reliable determination of relative humidity in concrete is important for floors with various types of tight coating, but also for different research purposes in order to evaluate and compare materials, various concrete compositions, binders, surface treatments etc.

Measurement of relative humidity in concrete is not straightforward. There are different types of measuring devices available and several types of errors exist, leading to uncertain and/or unreliable results. The main purpose with the workshop is to exchange experience from the use of different RH devices and the different measuring procedures applied in lab and in-situ, as well as experience from use of concrete made with different binders and self-desiccation concrete.

Relevant topics for the workshop were:

- Requirements and experience from use of different RH measuring devices/sensors and procedures for in-situ measurements
- Experience from relative humidity measurements in the laboratory and in-situ for research purposes (incl. various sources of errors)
- Utilization of self-desiccation concrete and effect from different binders on humidity development
- The experience from the use of different computer humidity calculation programs

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Participants

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Nina Plünnecke Borvik, Skanska, NO
Ola Skjølsvold, SINTEF, NO (organizer)

Presentations (enclosed in pdf-documents)

Paul Sekki: Modelling and measurement of RH in concrete
Peter Brander & Kent Bergstrøm: RH-measuring challenges. Moisture flow balance problems in vapor tight concrete & Heat effects from drilling
Sami Niemi: Finnish practice for RH measurements
Annika Gram: Zementestrich in Deutschland
Leif Wirtanen: New materials and design and the impact on RH in concrete, Finnish experience
Stefan Nordmark: The challenge of developing a moisture sensor that is cast into concrete
Jan Lindgård: Experience from RH measurements at SINTEF in general, with focus on use of Humigard
Bernt Kristiansen: Self-desiccation in concrete floors
Nina Plünnecke Borvik: Self-desiccation by the use of shrinkage reducing agents and other additives
Essence of presentations and discussions

Introduction

Questions about Relative Humidity (RH) measurements in concrete is a never-ending story both with respect to principle for measuring, equipment and accuracy. The recommended critical RH levels are the same as used the last 30-40 years. The procedures for determination of the RH in concrete have been improved over the last decades, but we are still wondering about what the real RH level in a given concrete is at a given time. At the same time, the concrete materials (i.e. type of cement, additions and w/c) and material combinations together with new knowledge have created new challenges regarding the relevance of the old critical RH levels. This was the basis for arranging a Nordic Workshop on Relative Humidity (RH) in concrete. The workshop was held at SINTEF Building and Infrastructure in Trondheim November 7th and 8th, 2018 (from lunch-to-lunch). In total, 11 participants took part.

Most presentations were connected to challenges with measurement of RH in concrete floors before applying the floor covering while other focused on the use of self-desiccation concrete. In the following a brief extract from selected presentations is given.

Principle for measuring RH

In most Nordic countries, the main technique for measuring RH in concrete (floors) is to drill holes before installing plastic tubes. Subsequently, calibrated RH sensors can be placed at the aimed depth. The RH is normally measured manually over time.

An alternative method is to collect concrete pieces from a structure, either by chopping or by drilling cores (with use of minimal water supply). In the laboratory, the collected samples are broken into smaller pieces that are put on a glass tube, before the RH sensor is installed and the glass tube is sealed and placed in a temperature stable chamber or room. This procedure is for example used extensively at SINTEF the last decade. The method is also used in Finland for documentation of RH in concrete floors, but it is banned in Sweden for floor measurements.

In Germany, different "floor concepts" and materials are used. Often, a mortar with earth-moist consistency is applied as the top layer. It is not usual to measure RH in-situ, rather (if measured) on chopped mortar lumps by use of Speedy moisture tester or similar.

Several RH sensors are also available for being cast into the concrete, but this principle and corresponding RH sensors are still not regarded accurate enough for being recommended for commercial use. Most of these RH sensors will also have problems at the highest moisture levels, and some sensors will also be destroyed if they are exposed to very high moisture levels (> 98 % RH) as you will have immediately after casting the concrete. However, in Sweden, a cast in system for wireless measurement of RH in concrete is soon ready for commercial sale. It has been difficult to find a RH sensor with satisfactory long-term durability, and it is still to see how this will work in practise.

Sources of errors – accuracy of RH measurements

Some countries allow repeatedly measurements over a long period with calibrated sensors in the same drilled hole. If the RH sensors meet the expire date (for example Humiguard sensors), they must be replaced with new sensors. However, this procedure is banned in Sweden due to the risk of permanent drying around the hole (connected to too low moist transport in low w/c concrete). Instead, new holes must be drilled if the measurements are to be continued over a long period. This conclusion is based on a Swedish study including different cement types and additives combined with a low w/c.
In Sweden, also the influence of any local heat development from different drills have been investigated. Some drills are specially designed for producing low heat development and thus to a lower extent increase the local temperature around the drill hole (that will influence the RH). "Normal" and worn drills can cause temperatures up to about 200⁰C around the hole, while the temperature achieved by using specially designed drills can be as low as 50-60⁰C. The local effects on the measured RH after heating to 200⁰C is depended on the measurement procedure applied. It is suspected that the initial registered relative humidity will be too high.

The RH measurement procedures have changed over the last decades (separate holes for measurements over time, the time elapsed before stable readings etc), but as far as floor coating is concerned, the critical RH levels correspond to those used 30-40 years ago. At that time, the measuring procedures were hardly accurate enough to distinguish between smaller RH differences in concrete and thus to accurately measure whether the concrete floor was dry enough for starting the flooring process. It is thus expected that a lot of incorrect measurements have been conducted over the years and consequently that the floor covering was placed on "too wet" concrete. However, since the concrete normally used was rather open (high w/c), after a period of drying it was able to absorb some of the extra water supplied by the glue (and screed). In many cases, this absorption was enough for preventing problems with loss of adhesion and emission from the glue. Inaccurate measurements have therefore not necessarily caused problems.

Accurate measurements of the moisture and moisture development over time will still be an important issue in research and development purposes, for example when the effect from different moist reducing efforts is to be studied. We should therefore not stop improving various systems for RH measurements, rather continue to investigate how to perform more accurate and reliable RH measurements in concrete.

Critical moisture levels for various floor coatings – risk of emission from the glue

For many floor coatings the critical moisture level is usually 85 % RH, i.e. the concrete floor must dry out to a level below the "equivalent RH" before flooring. These requirements only differ slightly between the Nordic countries. For example, in Finland the requirement is 75 % RH at depth 10-30 mm (w/c applied is typically 0.6-0.7) and 85-90 % RH in larger depths dependent on the coating type. The 85 % limit is an old criterion, and this value is hardly valid for all coating materials, in any case not for all types of coating, glue, screed and concrete combinations. A modernization of this value that takes these new materials (new binders and low w/c concrete) and material combinations into account is long overdue. Example: will the moist level for all new concrete recipes ever reach as low as 85 % RH, which they according to traditional calculations should? Some measurements indicate that this RH level is hard to fulfil.

The glue applied is usually not alkali resistant. Thus, some problems are expected with the introduction of new binders (more tight concrete) and water-based screeds and glues. Often, the coatings applied are also tighter than the previous types. Consequently, any excess water from the glue will not or only to a minor extent evaporate through the coating material. In Finland, the w/c normally used in concrete floors is 0.6-0.7, i.e. a rather open concrete that can absorb some excess water from the glue. This is expected to give less problems than for example in Sweden, where the w/c normally is well below 0.4.

In Finland, the number of cases with too high RH when applying floor coating and the consecutive problems with too high emission values is usually low. However, indoor climate is a difficult topic and some problems are still reported. A low number of reported damages is also the situation in Sweden, while only a few problems are reported in Norway. But, before concluding about the extent of coating problems and on the reasons for these problems, a more comprehensive survey/review should be performed.
Use of low w/c concrete – self-desiccation

The self-desiccation for concrete can be calculated. Theoretically, a CEM I (OPC) concrete with w/c 0.4 will achieve a long-term relative humidity of about 75%. In many cases, an epoxy coating can be applied within the first day when the temperature passes the maximum peak. Due to the "vacuum effect" (i.e. the concrete is in a suction state during the first day of hydration), the adhesion will be excellent, and the concrete moisture will not cause any problem when low w/c concrete is applied. In such cases there is no need for documentation by measurements of RH.

The use of self-desiccation concrete and the RH-level achieved is, however, disputed. On the one hand, accurate measurements are no longer necessary as these concretes are so tight that they do not expel any moisture in any case, and a moist profile is not likely to be achieved. On the other hand, these tight concretes without a moisture profile will hardly absorb any moisture from the screed and the glue. Thus, any water in the layer between the concrete and a tight coating will not have anywhere to go and might therefore cause problems if the glue contains water and is not alkali resistant.

However, theoretically all problems should be solved provided low w/c concretes are applied and the layer between the coating and the concrete (screed and glue) contains very little water.

Computer programs

Different computer programs exist for calculation of the RH development during drying. The accuracy of these calculations for new binders and "modern" concrete recipes are, however, disputed. In Finland, efforts are taken aiming to develop more accurate models for predicting the moisture development. The results are promising, but the work is far from completed. One of the major challenges is to make accurate measurements for calibration of the calculated values.
Modelling and measurement of RH in concrete

NORDIC Workshop on RH in concrete - Trondheim, November 7th - 8th 2018
Reasons for modelling?

• Geometry 2D and 3D
• Self-desiccation
• Temperature dependence
• Simulation of the construction phases
Hydration heat and moisture sink

Energy and mass balance equations

\[ \rho C_v \frac{dT}{dt} = -\nabla \cdot \left( k \nabla T \right) - Q + \dot{Q} \]

\[ Q = H_{\text{vap}} \frac{d\alpha}{dt} \]

\[ S = -\rho_{\text{vap}} M_{\text{vap}} \frac{d\alpha}{dt} \]

Degree of hydration and equivalent time

\[ \frac{d\alpha}{dt} = \exp \left[ \frac{E}{RT} \right] \frac{\alpha \beta}{\alpha_0 \beta_0} \left( \frac{T}{T_0} \right)^\theta \exp \left[ -\left( \frac{T}{T_0} \right)^\theta \right] \]

\[ D_{eq} = \frac{C_v}{\alpha_0 (1-\alpha_0) [1+\left( \frac{\alpha-\phi}{\alpha_0-\phi_0} \right)^n]} \]

\[ \frac{d\phi}{dt} = \exp \left[ \frac{E}{RT} \right] \left( \frac{T}{T_0} \right)^\theta \]

Optimized parameters: \( \beta, \tau, C_v, \alpha_0, \phi_0, \phi \)

// NSB2017 Sekki & Karvinen //
Temperature dependence

Boundary 5: 5 °C → 60 °C
Modelling "Layer cake"
Construction phases

1. Minimum effort
2. Flooring material
3. Shorter wetting time
4. Shorter wetting time and more time for drying

Exposed to rain
Exposed to humid condition
Drying condition
Testing and measuring

1. Material properties
2. Moisture measuring

www.tut.fi/rakennusfysiikka/combi
The Challenges of Measuring Moisture

1. Devices
2. Measuring methods
3. Temperature
4. Errors in several places
hoping to get some new ideas!

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RH-measuring challenges
Moisture flow balance problems in vapor tight concrete
Heat effects from drilling

Trondheim 20181107
Kent Bergström, Johan Tannfors,
Peter Brander (until 20180801)
Lars-Olof Nilsson, Moistenginst AB
Field operatives

Polygon/AK (regarding concrete)
- 33 RBK technicians
- Specialists in moisture safe design
- Specialists in moisture safe construction
  - Laboratory capabilities
  - Temporary climate solutions
- Moisture damage control, investigation, mitigation
It started out with a tool to evaluate field data. High readings and fast drying with low WCR?

We noted big spread in readings (low WCR with ongoing screeding.)
Always By Your Side.

Crawled before we tried to run
And then we made some more tests, and some more, and some more and... 2 years running now and still testing. What we found needs repeated readings over time to be able to see. Trends and behaviour not values put us on the right track. Mimicking field climate made new findings.

And it got really interesting.
It matched in situ data (2014-2018 900 readings)

Flow balance = we will always miss the target

<table>
<thead>
<tr>
<th>RH/vapor gradient</th>
<th>Relative resistance in concrete</th>
<th>Relative resistance in sleeve</th>
<th>Measured value inside hole (concrete 85%RH)</th>
<th>Season effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>20°C 85-20 RH</td>
<td>1</td>
<td>200</td>
<td>84,7</td>
<td>Winter</td>
</tr>
<tr>
<td>20°C 85-20 RH</td>
<td>1</td>
<td>100</td>
<td>84,4</td>
<td>Winter</td>
</tr>
<tr>
<td>20°C 85-20 RH</td>
<td>1</td>
<td>10</td>
<td>79,1</td>
<td>Winter</td>
</tr>
<tr>
<td>20°C 85-60 RH</td>
<td>1</td>
<td>10</td>
<td>82,7</td>
<td>Summer</td>
</tr>
</tbody>
</table>
The "balance error" will typically increase over time and vary by drying climate.

- Will change by temperature (vapor content in concrete)
- With decreasing total vapor gradient the error can vanish
- Will change by vapor content in air

Vapor gradient (concrete / hole) 85%
Vapor gradient (hole / drying climate) 20%

Concrete resistance
Sleeve resistance

- Will always increase by time due to drying of the surface in the hole and by maturing processes in the concrete that add resistance. Will decrease with higher temperature.
- Can decrease by time due to mechanical damage...
  - Decrease in vapor open materials

Leakage and resistance will effect how flowbalance is reached

 Actual values
 Reachable values
 Leaky values

We will always target absorption first. To reach desorption we need the surface in the hole to start drying. This will introduce a moisture profile in the hole that will increase the balance error. When desorption balance is reached is hard to predict and evaluate. The measured RH error can be huge if the desorption isotherm is flat and the sleeve fitting is leaky.
The timeframe depends by diffusion to and from the hole and also include buffering effects.

Better sleeve techniques have transformed normal readings from red towards green. High sensor buffering will also slow down the absorption process and promote lower early readings. Note! No drying of concrete in this example.

We get vapor transport around fittings (through concrete) and towards the vertical moisture profile.

Leakage through levelling products was found to add big balance error.

Too high readings if wet
Too low if dry!
It's possible to model the behaviour

Left with no sleeve leakage in concrete
Right adding vapor open screed and airgap between sleeve and concrete

Steel jars from top and side 7 and 50 days, at same depth

Note: Not the actual moisture level that is measured. Moisture in the surface of the hole minus balance error is measured.
Flow balance issues will result in different readings

If the balance is changed after a formed drying profile in the hole we get change in readings

New tighter sleeve and added exposed area in leaky old hole
The good old days when concrete dried by itself?

Wcr 0.32
1d 16% off
3d 9% off
7d 4% off

Leaky fitting with high sensor capacity

Or not?
Heat effects will add issues

When does it happen?

- Three different flow balance behaviour depending on drillbits
Concrete loose moisture capacity when heated (and loose vapor balance issues?)

Drilling several holes in sequence (profile drilling) or deep holes will increase energy transfer. Low wcr concrete will get warmer (harder).

<table>
<thead>
<tr>
<th>Depth [mm]</th>
<th>New drillbit [°C]</th>
<th>Wearad drillbit [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>88</td>
<td>114</td>
</tr>
<tr>
<td>100</td>
<td>89</td>
<td>177</td>
</tr>
<tr>
<td>150</td>
<td>94</td>
<td>191</td>
</tr>
</tbody>
</table>
Heat effects when drilling without cooling

- **0-1 (appr. 30s)** Drilling (rapid heating, possibly additional moisture to holesurface from drilldust, high vapor content, steep vapor and heat profiles)
- **1-2 (1-10min)** Cleaning (rapid cooling and surface drying, recondensation in porestructure, steep vapor and heat profiles)
- **2-3 (0,1-3h)** Capped hole (surface is rewetted from within concrete, concrete is still cooling near the surface)
- **3 (3-48h)** Temperature is stable, Maximum RH is reached in most cases
- **3-4 (3h-14d)** Surface in the hole starts scanning towards desorption...
- **4** Drying progresses within the hole through leakage and moisture profile development.

Adding heat increase early readings, possibly mainly by better flow balance (higher vapor pressure)
High early readings often described as a drill error to wait for. Compared to capped steel jars it’s probably mostly absorption reading. More exposed concrete area and improved fitting delayed desorption.

Drillbit strategy can change the initial conditions.

<table>
<thead>
<tr>
<th>Depth [mm]</th>
<th>Hilti 16mm [°C]</th>
<th>Hilti cooled [°C]</th>
<th>Dewalt cooled [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>55</td>
<td>34</td>
<td>26,8</td>
</tr>
<tr>
<td>100</td>
<td>59</td>
<td>34,8</td>
<td>26,2</td>
</tr>
<tr>
<td>150</td>
<td>65</td>
<td>35,2</td>
<td>28,1</td>
</tr>
</tbody>
</table>
Change in behavior due to cooling and conditioning, different sensors. Early balance

And now together!
Horizontal drilling in a testbed (shouldn’t have a profile) different drill depths 50, 100, 150mm, warm vs cooled. Depth increase exposed concrete area!

Wcr 0.34, 15% slag 1.5 years old

Old warm drilling in capped jars (dark red new sensors) vs New cooled (blue) and new varm (light red), 50, 100, 150mm drill depth.

With tight sleeve fittings we get no effect from drilldepth! ( ) probably leaky
Measured profile probably often something else than drying?

Different drill depths will show different vapor gradient towards the lower sleeve fitting and change the balance.

Could it be absorption readings altogether?
Cooled drilling without extra area is much faster to desorption readings (– extra balance error?)

Conclusions

Challenges
- Risk = absorption situations
- Moisture flow balance needs to be better explained in standards.
- Heat effects when drilling need more testing to quantify
- Temperature effects in service is not fully explained yet, underfloor heating?
- Critical moisture limits on which sorption curve or both? Measured how? for which temperature?
- Desorption readings need leaking sleeves. Desorption readings include very flat scanning curves which make it harder to get repeatable readings with low wcr.

Possibilities
- We can use loggers to see trends
- We can reach fast flow balance on absorption (few hours)
- We can force readings near desorption fast by cooled drilling or crushed samples.
- We could address moisture flow more than RH.
- We can make holes without adding heat.
The actual risk depends on several additional factors. This is what we probably should discuss.

- climate above
- flooring
- adhesive
- levelling products
- concrete
- additional design layers
- climate beneath
And it is still interesting!

Risk with vapor tight flooring?

Induced Summer conditions by 75%RH
Finnish practice for RH measurements

Sami Niemi, M.Sc.
Vahanen Building Physics Ltd
CORNERSTONES OF TODAY’S SITUATION IN FINLAND

• Vaisala and VTT since 80’s
• 1995 learn from Sweden (Humittest Ltd, joined Vahanen at 2006)
• 1998 RT-instruction card (“normal quality of construction”)
• 2003 start of teaching of certified measurers (VTT, Humittest/ Vahanen)
• 2007 construction industry’s measurement guidelines
• 2010 RT-instruction card = PRACTICAL
• 2010’s focus has been in common moisture control of constucting
RH MEASUREMENTS IN CONCRETE (RT 2010)

• Practical guide to get proper enough readings
• Exact measurements (10 of 16 pages about one RH-reading)
• Directional measurements
• Factors affecting measurement accuracy
• Measurement before coating and coating rating
• Research of the finished structure

BOREHOLE METHOD
• Temperature 15 … 25 °C
• If not in a hurry – easily lot of measuring spots

SAMPLE METHOD
• Temperature -20…80°C
• Poor conditions (hot or cold concrete)
• Better accuracy - more difficult, but the result becomes faster
The effect of sealing on concrete measurement (RH)

Surface parts of the concrete are much dryer than concrete at measuring depth.

Probe (HMP44) stabilization in hole/measuring tube is 1 h.

Stabilization times of different probes VCR 0.65 and RH 85%
SAMPLE/ TEST TUBE METHOD

Test tube Air space, where equilibrium RH is measured

Cuts from the bottom of the shaft, not 5 mm closer to the edge of the bore

Minimum volume of the cuts is 1/3 of the test tube’s volume

Cuts in to the test tube
Stabilization in test tube/ sample method

- OL - 1cm
- OL - 4cm
- K30 (7kk) - 1cm
- K30 (7kk) - 5cm
- K30 (7kk) - 5cm vähän
- NP40 (7kk) - 5cm
- NP40 (7kk) - 5cm vähän

OL = Old hollow core
K30 = VCR 0.7
NP40 = faster drying (extra air + VCR 0.50)
kk = month
Vähän = less cuts than normal

RH (%) vs Hours in testtube
The inaccuracy of the drill hole measurement, the concrete surface is drier than the interior

Possible magnitudes and directions of the error

- the type of the probe
- time from the previous calibration
- the number of probes used and the measurement points
- calibration and checking accuracy
- cleaning the hole
- piping of measuring hole
- sealing of the measuring tube
- stabilizaton time of the probe in the tube
- waiting time from drilling
- correct measuring depth
- the structure temperature abnormal
- the temperature difference between the structure and the upper air
Accuracy factors in sample method, concrete surface drier than interior

Possible magnitudes and directions of the error

- the type of the probe
- time from the previous calibration
- the number of probes used and the measurement points
- calibration and checking accuracy
- cleaning the measuring bore
- sample Number
- sealing of the test tube
- Stabilization time of the probe in the test tube
- the waiting time for concrete machining
- correct measuring depth
- the structure temperature abnormal
- the temperature difference between the structure and the upper air
**MEASURING DEPTHS BEFORE COVERING**

- **Intermediate floor (drying both sides)**: $A = 0.2 \times d$
- **Joint slab or slab on ground (drying one sided)**: $A = 0.4 \times d$
- **Partly pre-cast intermediate floor**: $A = 0.2 \times d$
- **Hollow Core slab + upper concrete ($d_2$)**: $A = d_2 + 20 \text{ mm}$
- **Hollow Core slab + screed ($d_2$)**: $A = d_2 + 20 \text{ mm}$
- **Dumped Hollow core + bathroom floor**: $A = 0.4 \times d_2$

Always at least two depths

Maximum measuring depth 70 mm

the choice of measurement point place and the representativeness of the result

2007
### COVERING LIMITS

<table>
<thead>
<tr>
<th>Coating material</th>
<th>Evaluation of Concrete RH (%) by depth A</th>
<th>Concrete and / or smoothing RH (%) on the surface (0-5 mm) and 1-3 cm deep (0.4*A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVC carpets</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>Linoleum carpets</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>Rubber carpets</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>Textile mat, vapourtight base (pvc, rubber, rubber latex) or natural material</td>
<td>85</td>
<td>75</td>
</tr>
<tr>
<td>Full synthetic textile mats without a substructure</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>Plastic, rubber, linoleum tiles</td>
<td>90</td>
<td></td>
</tr>
</tbody>
</table>
Observe the moisture content of the screed and the glue.
“rapid RH-measuring under elastic covering, so called cut-method”
DIRECTIONAL MEASUREMENTS

• Measurement of non-piped holes
• Measurement repeatedly from the same measuring tube
• Measurement of the measuring tube mounted on the cast
• Measuring soon after drilling
• Measuring continuously with the sensor inside the concrete
• Measurement outside the recommended temperature range
• Sample measurement without installing the probe immediately into the test tube
• Sample measurement with less than normal cuts or inaccurate depth
MONITORING IS POPULAR

• IoT-based concrete drying conditions management - NCC
• Smart Concrete – Luja Betoni
• Construction site Digi engineer – Bliot Oy
• RamiSmartTM condition monitoring – Ramirent
• Monitoring probes + wireless data transfer
  – RFSensit
  – Viiste
  – Simap
  – Others
• Vaisala is still number one in Finland
MORE MEASUREMENTS ARE DEMANDED AND DONE ALL THE TIME

NEW MEASURING EQUIPMENT AND TECHNIQUES ARE BEING DEVELOPED

MOISTURE PROPERTIES OF MATERIALS SHOULD BE KNOWN BETTER

THE INSTRUCTIONS SHOULD BE REFINED
FUKT OCH MÄTNING I TYSKLAND

Trondheim
Annika Gram
2018-11-07
RISE CBI Betonginstitutet AB
Schäden in der Praxis durch zu frühes Belegen

Quellen von feuchteempfindlichen Belägen
Schäden in der Praxis durch zu frühes Belegen

Blasenbildung (PVC)

Verseifung des Klebers
Vad är en Estrich?

Översättning: flytspackel, avjämningsmassa
Schwimmender Estrich – flytande golv

WAS IST ESTRICH?
Estrich ist die Abdeck- und Begradigungsschicht, die auf das Betonfundament gegeben und eben abgezogen wird. Estrich kann dabei aus ähnlichen Bestandteilen bestehen wie Beton, jedoch gibt es verschiedene Arten von Estrichen. Oder anders gesagt: Beton wird durch seine Bestandteile definiert; Estrich wird durch seine Funktion definiert.
Diese Arten von Estrich gibt es:
• Zementestrich (CT)
• Gussasphalttestrich (AS)
• Kunstharzestrich (SR) (t ex epoxi)
• Calciumsulfatestrich (CA)
• Magnesitestrich (MA)
ZEMENTESTRICH
Zementestrich in Deutschland

→ Internationale Normen für Stoffe und Prüfungen

EN 13813: Eigenschaften und Anforderungen, Klassifizierung
EN 13892: Probenahme, Prüfverfahren

→ Nationale Anwendungsregeln

DIN 18560: Anforderungen, Dimensionierung, Ausführungen, Prüfumfang
DIN 18353: Technische Vertragsbedingungen

Die „Belegreife“ (max. Feuchte des Estrichs) ist nicht normativ geregelt! Hierfür werden z.B. Merkblätter von Fachverbänden verwendet
Trocknungsverhalten von Zementestrich

- Estrichmörtel mit Hochofenzementen wiesen nach einer Lagerung von bis zu einem halben Jahr im Klima 20°C/65% r. F. höhere Feuchtgehalte (CM-Feuchte und mittels Ofentrocknung bei 105°C bestimmter Massenanteil der enthaltenen Feucht) auf als Estriche mit anderen Zementarten (Bild 1).

- Zementsteine mit Hochofen- und Portlandhüttenzementen zeigten bei Lagerung in den Klimaten 20°C/65% r. F. und 40°C/30% r. F. deutlich geringere Massenverluste und beim Klima 20°C/65% r. F. bereits nach wenigen Wochen Massenkonstant, d. h. es wurde keine weitere Baustofffeuchte in die Umgebung abgegeben.


Zementhersteller 1
Estrichzusammensetzung:
Zement 300 kg/m², w/z = 0,65,

Nutzungsbeginn und Belegreife

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>begehbar nach</td>
<td>≈ 2 bis 3 Tagen</td>
</tr>
<tr>
<td>belastbar nach</td>
<td>≈ 10 Tagen ¹</td>
</tr>
<tr>
<td>belegbar nach</td>
<td>≈ 28 Tagen ²</td>
</tr>
<tr>
<td>Belegreife für beheizte Estriche mit elastischen und textilen Bodenbelägen, Laminat, Parkett und Holzpflaster</td>
<td>≤ 1,8 [M.-%] Feuchte des Estrichs ³</td>
</tr>
<tr>
<td>Belegreife für keramische Beläge auf beheizten oder unbeheizten Estrichen</td>
<td>≤ 2,0 [M.-%] Feuchte des Estrichs ³</td>
</tr>
<tr>
<td>Belegreife für unbeheizte Estriche mit elastischen und textilen Bodenbelägen, Laminat, Parkett und Holzpflaster</td>
<td>≤ 2,0 [M.-%] Feuchte des Estrichs ³</td>
</tr>
<tr>
<td>Belegreife für dampfdurchlässige textile Beläge bzw. Fliesen/Naturstein / Betonwerkstein im Dickbett, Estrich beheizt und unbeheizt</td>
<td>≤ 3,0 [M.-%] Feuchte des Estrichs ³</td>
</tr>
</tbody>
</table>

¹) Bei Verwendung von Zement der Festigkeitsklasse CEM 42,5; = 7 Tage
²) Grober Anhaltswert. Gilt für Estrichdicken bis 50 mm; bei dickeren Estrichen mindestens ~ 5 Tage/cm Mehrdicke zurechnen. Zur Kontrolle Feuchtigkeitsmessung durchführen.
³) Feuchtigkeitsgehalte gelten bei Messung mit CM-Gerät (Calciumcarbid-Methode), siehe [26]; [16]

<table>
<thead>
<tr>
<th>Bodenbelag</th>
<th>Feuchtigkeitsgehalt bei Zementestrich</th>
<th>Feuchtigkeitsgehalt bei Anhydritestrich</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stein- und keramische Beläge im Dünnbett</td>
<td>2,0</td>
<td>0,5</td>
</tr>
<tr>
<td>Stein- und keramische Beläge im Mörtelbett auf Trennschicht</td>
<td>2,0</td>
<td>0,5</td>
</tr>
<tr>
<td>Stein- und keramische Beläge im Dickbett</td>
<td>2,0&lt;sup&gt;1)&lt;/sup&gt;</td>
<td>0,5&lt;sup&gt;1)&lt;/sup&gt;</td>
</tr>
<tr>
<td>Dampfdurchlässige textile Bodenbeläge</td>
<td>3,0</td>
<td>1,0</td>
</tr>
<tr>
<td>Dampfbremsende textile Bodenbeläge</td>
<td>2,5</td>
<td>0,5</td>
</tr>
<tr>
<td>Elastische Bodenbeläge z.B. PVC, Gummi, Linoleum</td>
<td>2,0</td>
<td>0,5</td>
</tr>
<tr>
<td>Parkett</td>
<td>2,0</td>
<td>0,5</td>
</tr>
</tbody>
</table>

<sup>1</sup) Bei feuchtigkeitsabsperrenden Haftbrücken (geplante Änderung)

**Tabelle 1** Für die Belegreife der Bodenbeläge maßgebende maximale Feuchtigkeitsgehalte von Estrichen nach DIN 4725 Teil 4
Calciumcarbid-Methode

https://de.wikipedia.org/wiki/Calciumcarbid-Verfahren

\[ \text{CaC}_2 + 2 \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2 + \text{C}_2\text{H}_2 \]
Wie hoch darf der Feuchtigkeitsgehalt in Bauteilen sein, damit sie zur Weiterverarbeitung geeignet sind?

A. Beton und Leichtbeton
   für Korkparkett, Korklinoleum, Spachtelböden, Steinholz
   für Linoleum
   für Holzparkett
   für sehr dichte Beläge (Gummi und PVC)
   6,0 %
   4,5 %
   3,5 %
   2,5 %

B. Magnesit-Estriche (Steinholz) 9,0—11,0 %
   (je nach Füllstoff)

C. Gips-Estrich, Anhydrit-Estrich 1,0 %

D. Mauerwerk, Innen- und Außenputz 2,0 %

E. Füllmaterialien zwischen Holzbalkendecken mit Holzdieleung 3,0 %

Werden diese Feuchtigkeitsgrenzen überschritten, dann muß mit Isolierung gearbeitet werden.

Zur Beachtung:
Feuchtigkeitsbestimmungen sollen möglichst nicht bei Temperaturen unter 0 °C durchgeführt werden. Die Probenahme des Prüfgutes soll an den Stellen erfolgen, die dem Verleger als besonders feuchtigkeitgefährdet bekannt sind oder erscheinen.
Kritiska fukttillstånd – RF$_{krit}$

enl. Åhs & Nilsson (TVBM-7203, 2010)

De kritiska fukttillstånd som används idag har på sätt och viss ”levt kvar” från 1970-talet, men sänktes under 1990-talet, då en extra säkerhetsmarginal drogs ifrån.

"Gamla värden på kritiska fukttillstånd fanns i HusAMA fram till 1983, uttryckta som ”CM-%” (CM=karbidmätare). Lars-Olof Nilsson gjorde en ”översättning” av dessa CM-% till Relativ Fuktighet RF till Råd och Anvisningar till HusAMA RA78.

Denna ”översättning” hade mycket liten vetenskaplig grund och var mer baserad på vad som var rimligt och acceptabelt för materialleverantörerna respektive byggnadsentreprenörerna.

Översättningen utmynnade i ”jämna siffror” som 95, 90 och 85 % RF.

På den tiden kunde man inte mäta RF särskilt noggrant så det fanns ingen anledning att nyansera värdena mer.
Uttorkning av byggfukt i betongplatta med ingjuten värmekabel

Slutsatsen som kan dras i projektet är att uttorkningsmetoden med ingjutna värmekablar är bra uttorkningsmetod. Svårigheterna med metoden är det idag inte finns lämpliga bedömnings-hjälpmedel som kan användas för att uppskatta uttorkningstiden. De teoretiska bedömningarna försvaras av att det är temperaturgradienter i betongen. Vid val av mätmetod i projektet var kunskapen ej etablerad om att den mest lämpliga mätmetoden är uttaget prov vid fuktmätning i betonggolv med värmekablar. Den valda mätmetoden med kvarsittande givare visade sig ge osäkra mätresultat.
Uttorkning av byggfukt i betongplatta med ingjuten värmekabel

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NEW MATERIALS AND DESIGN AND THE IMPACT ON RH IN CONCRETE, FINNISH EXPERIENCE

NORDIC WORKSHOP ON RH IN CONCRETE, TRONDHEIM, NOVEMBER 7TH -8TH 2018

Dr. Leif Wirtanen, Ramboll Finland
AGENDA

1. CONCRETE
2. STRUCTURES
3. ADHESIVES
4. SCREEDS
5. FLOORINGS
Δ supplementary cementitious materials (GGBS)

Δ admixtures (superplasticizers)
STRUCTURES

Δ thicker

Δ more complex
ADHESIVES

Δ binder (acrylic / EVA...)

Δ additives (2EH)
SCREEDS

Δ alkalinity (aluminacement, gypsum)

Δ layer thickness (increasing)
Δ denser (PU treatment)

Δ composition (phthalate free plasticizers/adipates, aliphatic esters...)
DO WE MEASURE THE RIGHT THINGS (RH, VOCs) IN THE RIGHT WAY?
QUESTIONS AND ANSWERS
THANK YOU
Stefan Nordmark
Electro-tech
Elara2
Elara2

We have been developing the humidity sensor during a period of 3.5 years and are now in the final phase of tests which be will done at University of Lund during 2019-Q1/Q2

Presentation by Stefan Nordmark
Elara2
Challenge

Sensor Chip
Will it work in concrete
Accuracy of the sensor over time

Mechanic
How shall it be designed
Membrane
Plastic housing

Communication
868 MHz
868 MHz Lora

Life span
Time 9 year
This is how the system works

Wireless measuring of the humidity in concrete

The RFID-tranponder, which contains a sensor and a transciever, is cast into a concrete structure. Data from the tag is transmitted to an external access point in the vicinity of the concrete structure.

The external access point is connected to internet via GPRS. The information is sent to a database.
Advantages

• 1. Continuous monitoring from day zero via computer, tablet or mobile phone
• 2. Installation of sensor in the design is less than 2 minutes
• 3. Archiving data as well as easily copying the information / data into your reports
• 4. We store all data in servers that you have access to
• 5. No physically need to be in place to decide on any action for the occasion
• 6. Documentation to easily show status
• 7. Planning tool Qa
The presentation is now over, thanks!
Experience from RH measurements at SINTEF in general, with focus on use of Humiguard

Senior Scientist (PhD) Jan Lindgård, SINTEF

Content
- Background
- RH systems used at SINTEF (concrete)
- Main experiences; some pros and cons
- Improvement of the Humiguard system
- Summary

Background
- Long experience with use of RH measurements in various R&D projects
  - Often linked to PF/DCS measurements
- Laboratory measurements
  - Internal RH in various lab. cast samples (mainly ASR)
  - Internal RH in drilled cores from field (mainly ASR)
  - Simulating drying of concrete floors (various binders)
- In-situ measurements
  - Concrete structures (mainly bridges)
  - Field exposed samples (laboratory cast – stored at exposure sites)

Example: Field exposed samples in Trondheim. Are various surface treatments able to reduce the intern RH?
Main RH systems used at SINTEF

- Vaisala "HMP44" (www.vaisala.com)
  - Mainly lab. measurements
  - Long experience – extensively used last 10 years

- Humiguard (www.industrifysik.se)
  - Mainly field measurements
    - RBK: concrete floors
    - About 20 years of experience
      - Various R&D projects (incl. aim to improve the accuracy)
    - MSc study in 2017 (NTNU)

Procedure for use of Vaisala sensors for lab. measurements

- Calibration of each sensor before and after measuring
- Splitting and crushing of concrete (avoid losing moisture)
- Collection of small paste samples (3-6 mm from the interior) on glass tubes
- Installation of RH sensors after about 1-2 hours of pre-storage in the 20°C climate room (avoid condensation)
- Storage of the glass tubes in an "insulation block" (keep the temp. stable)

Procedure for use of Humiguard sensors for field measurements

- Daily measurements for 4-5 days (in the morning – stable temp.)
- The readings after 2-3 days are normally used
- Calculations based on the recent calibration performed (before and after)

- Drill and clean the holes, install the plastic tubes (incl. use of a sealing compound along the tube; e.g. "Sikaflex") and seal the top
- Install RH sensors 1-2 days after drilling
- Insulate the plastic tube and seal (reduce the influence of temp. variations)
- Wait 5-7 days before the first measurements
- Measure when stable temp. over at least a 24 hours period and when cloudy (preferably stick to one temp. level; in Trondheim from 15-20°C)
- Avoid heating by the sun (protect the samples if sunshine)
Main experiences; some pros and cons

<table>
<thead>
<tr>
<th>System</th>
<th>Vaisala (V)</th>
<th>Humiguard (HG)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy</td>
<td>0-90 % RH: ± 2 %</td>
<td>About ± 2 % at 85 % RH</td>
<td>Data from the producers</td>
</tr>
<tr>
<td>Calibration</td>
<td>Yes, preferably before and after measuring (+)</td>
<td>No need (+)</td>
<td>The accuracy of the HG sensors has been improved (+)</td>
</tr>
<tr>
<td>“Stability”</td>
<td>Normally only minor drift over time (+)</td>
<td>Drifting over time, thus need of ref. readings (-)</td>
<td>HG: the reference readings must be performed frequently (-)</td>
</tr>
<tr>
<td>Lifetime</td>
<td>Long (+)</td>
<td>Expire date 6 (27) months (-)</td>
<td>Need to replace the HG sensors every season. Complicated (-)</td>
</tr>
<tr>
<td>Costs</td>
<td>Rather expensive (-)</td>
<td>Rather cheap to buy (+), but costly over time (-)</td>
<td>Need of more manhours for using the HG system (-)</td>
</tr>
<tr>
<td>Temp. range</td>
<td>Long interval (?)(+)?</td>
<td>0-40 °C, but basically in the interval 15 to 25 °C</td>
<td>HG: Can &quot;fool&quot; the system if the temp. is outside this interval</td>
</tr>
<tr>
<td>RH levels</td>
<td>0-100 % (+)</td>
<td>Only in the interval 75-98 % RH (-)</td>
<td>Vaisala: The accuracy decreases at very high RH</td>
</tr>
<tr>
<td>Calculations</td>
<td>Easy and fast (+)</td>
<td>Complicated. Must use an on-line program (-), but aut. calculation to 20 °C (+)</td>
<td>HG: Possible to &quot;fool&quot; the system if too old sensors or temp. outside the given interval</td>
</tr>
<tr>
<td>Measuring depth</td>
<td>If shallow boreholes, use an &quot;installation cover&quot; (+)</td>
<td>Can measure in rather shallow boreholes (~5 cm)</td>
<td>Shallow boreholes more influenced by outdoor temp. &amp; sun</td>
</tr>
</tbody>
</table>

Many important sources of error exist

- Unstable (varying) temp. in the concrete (cold nights – warm and sunny days)
  - Lack of equilibrium between the concrete and the air in the borehole (see examples*)
  - Use of insulation in the tubes and covering the samples/structure will help

Examples on how to measure close to a concrete surface

- Drill holes from the side (deep to be less influenced by the outdoor temp.)
- Preferably, place the sensors away from the sun (NE) + insulate the tube

Importance of having the same temp. at the RH probe and the concrete

- Example Vaisala (from the user manual)
Many important sources of error exist

✓ Condensation any problem?
  o SINTEF lab:
    ▪ Installation of Vaisala sensors in the glass tubes after about 1-2 hours of pre-storage in the 20°C climate room (avoid condensation).
  o Condensation problems in field?
    o NS 3511: At installation, the RH probes should not have lower temp. than the concrete
    o Vaisala: (user manual)
      ▪ The RH probes start to function again as soon as the water has evaporated
      ▪ If contaminated water, shortened life span and drift of the sensors
  o Can HG sensors withstand condensation?

✓ How long can a drilled hole be used for measuring?
  o Dependent of the concrete quality and the moisture state?
    ▪ Any leakage might influence the RH (normally reduced)
  o Influence of the moisture capacity of the RH probe?
    ▪ When replacing the sensors, will the time to reach equilibrium increase? (longer time for denser and dryer concrete?)

Many stable (varying) temp. in the concrete (cold nights – warm and sunny day)

✓ Lack of equilibrium between the concrete and the air in the borehole
  o Use of insulation in the tubes and covering the samples/structure will help

✓ Too short time from installation of sensors to the readings are taken
  o General: Many examples on too early readings (i.e., will measure a too low RH)
    o NS 3511: > 15 (v/c>0.4) and > 48 t (v/c<0.4)
  o Vaisala: (User manual)
    ▪ Recommended to wait three days from drilling to measuring RH
    ▪ The RH probe can be installed immediately after drilling or before measuring
    ▪ If installed before measuring, seal with a rubber plug and wait about 30 minutes before measuring (too short time)

Calibration and drift of sensors

✓ Humiguard (HG):
  ▪ Do the reference sensors represent the installed sensors? (improved – see later example*)
  o Vaisala (lab.):
    ▪ How long should the RH sensors rest in room climate before moving from one glass tube to another? (relevant when moving to a dryer environment)

Production of RH sensors at Industrifysik

✓ Previously rather large spread between individual RH sensors

✓ Actions taken during the last years to increase the reliability and the accuracy
  o New system introduced in 2018
    ▪ All RH sensors are pre-tested
    ▪ Automatic selection of RH sensors in a narrow range (various groups)
  o Ref. RH sensors selected from the “mid part” of each sensor group

Improvement of the Humiguard system

✓ Aim to increase the reliability in RH measurements
  o Previously: Received RH sensors from a “large group” with unknown spread
  o Latest years: Hand selected RH sensors
  o MSc study in 2017 (NTNU)
SINTEF: Example of spread measured between reference Humiguard sensors

Figure 1: Curves for all reference readings 2014-2016

Figure 2: Calibration of old sensors at Voll test site. Calibration at 84.5% RH

Figure 3: Drifting of salt condensation in reference readings with 84.5% RH and spreading for 18 sensors located in different salt and reference readings with 84.5% RH.

Figure 4: Temperature and humidity readings from Humiguard sensors, showing spread and stability over time.
It is possible to measure RH rather accurately, provided care and actions are taken:
- If incorrect, often too low RH measured (many examples exist)
- Main sources of errors:
  - Improper sealing leading to leakage
  - Temp. variations between the RH probe and the concrete
  - Reading after too short time
  - Lack of calibration of the RH probes

SINTEF experiences:
- Vaisala (normally) works very well in the lab.
- Humiguard accuracy improved
  - Despite short expire date, the system works pretty well for field measurements
Self-desiccation concrete in floors

Bernt Kristiansen
AF Gruppen Norge AS

Materialer og konstruksjoner skal være så tørre ved innbygging/forsegling at det ikke oppstår problemer med mugg- og soppdannelse, nedbrytning av organiske materialer eller økt avgassing.

*Materials and structures should be so dry when installed / sealed that there are no problems with mold and fungus formation, organic matter decomposition or increased degassing*
Self-desiccation concrete

Ref.: BETONGENS FUNKSJONSDYKTIGHET. Delrapport nr. 30, Erik J. Sellevold. STF 65, A 88093. FCB, Trondheim.

SINTEF report from 1988
Self-desiccation concrete

T. Kanstad 1990: Dr. avhandling

\[ RF_{sf} = (0.0351 \times \ln(t) + 0.223) \times \left(\frac{v}{c}\right) - 0.051 \times \ln(t) + 0.78 \]

<table>
<thead>
<tr>
<th>Tid, mnd</th>
<th>Relativ fuktighet, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>0.4</td>
</tr>
<tr>
<td>6</td>
<td>0.6</td>
</tr>
<tr>
<td>9</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td></td>
</tr>
</tbody>
</table>
Use of self-desiccation concrete in practice

• Casting concrete floor at NORA, Brumunddal in 1989.
  • v/c-level 0,4
  • Epoxy mortar applied the day after casting.
• During 1990s it was several concrete floors in food industry casted with self-desiccation concrete and epoxy applied the day after casting.
Use of self-desiccation concrete in practice

- **Friday:**
  - Concrete casting, v/c = 0,4.
    - Or dry mortar Confix with 2,3 l water and 0,2 l melamin pr. 25 kg bag.
  - Cover with plastic
- **Saturday**
  - Morning: Remove plastic
  - When the concrete surface is light gray
    - After app. one hour
  - Epoxy primer applies
  - Evening: more epoxy
- **Sunday**
  - Topcoat epoxy
- **Monday**
  - Work at the food industri
Lifecycle concrete

[Graph showing the lifecycle of concrete with stages labeled as Setting, Hardening, and Use over time (Time, Days, Year).]
Temp gulvstøp Risløkka 2012
Use of self-desiccation concrete in practise

• I started in AF 1998 and started to measure RH development in different concrete mixes.
• From year 2000 AF started to use concrete with self-desiccation properties in a bigger scale on «real» projects.
Measuring relative humidity in different concrete mixes

<table>
<thead>
<tr>
<th>Resept nr.</th>
<th>Sementtype</th>
<th>V/C-tallet</th>
<th>Synkmål [cm]</th>
<th>Utbredingsmål [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Aalborg Rapid</td>
<td>0,35</td>
<td>22,0</td>
<td>45-50</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>0,26</td>
<td>22,0</td>
<td>43-47</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>0,58</td>
<td>20,0</td>
<td>35-37</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>0,45</td>
<td>22,0</td>
<td>35-37</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>0,45</td>
<td>22,0</td>
<td>37-39</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>0,40</td>
<td>21,0</td>
<td>33-36</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>0,40</td>
<td>22,0</td>
<td>36-42</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>0,40</td>
<td>24,0</td>
<td>52-53</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>0,40</td>
<td>22,0</td>
<td>51-53</td>
</tr>
<tr>
<td>10</td>
<td>Svensk SR</td>
<td>0,40</td>
<td>20,0</td>
<td>30-34</td>
</tr>
<tr>
<td>11</td>
<td>Aalborg Rapid</td>
<td>0,35</td>
<td>20,0</td>
<td>37-38</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>0,60</td>
<td>21,0</td>
<td>37-39</td>
</tr>
</tbody>
</table>
Relative humidity in concrete

Total weight loss 1-3 g pr. 1 year
Relative humidity in concrete

Calibration
After app. 100 days the sensors was calibrated
RH=75 % temp. = 20 ℃
6 sensors was exchanged, of 42
The rest was within ± 0,6 %.
Stated measurement uncertainty ± 1,0 %.
Relative humidity, self-desiccation
Hydratasjonsgrad
Shrinkage
Shrinkage:
- C25 from 1999
- B35M40 from 2012
2008: «Low-heat» concrete

- CEM I 260 kg
- Flyveaske 130 kg
- Water/cement-ratio 0.4

Self-desiccation
Shrinkage and relative humidity

Norcem STD FA v/c-tall 0,40

RF, %
Svinn, o/oo
Våler i Østfold, 2010

B30M60
Med hardbetong
Svinnkompensert med ekspansjon
Fiberarmert
Feltstørrelse: 70 x 30 m²
Våler, 2010
Målt 2012

3,5 mm åpning < 0,1 o/oo
Våler, 2010
Målt 2016

7,0 mm åpning
Ca. 0,14 o/oo
Industrigulv Fredrikstad, 2012
Befaring des. 2015

B30M60
Med hardbetong
Svinnkompensert med ekspansjon
Fiberarmert
Feltstørrelse: 50 x 30 m²

17 mm åpning
Ca. 0,35 o/oo
Hvorfor er gulvene så forskjellige?

Støpt 2012
B30M60
Betong:
Luft:
- RF: 32-37 %
- Temp: 18-25 °C

Betong:
- RF: 68-75%
- Temp: 18-21 °C

Støpt 2010
B30M60
Luft:
- RF: 32-35 %
- Temp: 17-18 °C

Betong:
- RF: 93-95%
- Temp: 16 °C
Hotel Park Inn, Gardermoen

2010
No joints

Water pipes
Concrete: B35M40
Reinforcement: $2 \times A_{\text{min}}$

20 mm etafoam
- Concrete composition
  - least possible cement paste
  - v/c-tall 0,4
- Slump 20 cm, "cream consistency"
- pipe: 3"
- Dissing + plastic
- Tiles or screed with coating
Sykehuset i Østfold

30,000 m² 40-90 mm concrete floor on hollow deck
No time for desiccation
40-90 mm concrete
Reinforcement K335
Sykehuset i Østfold

B35M40
SCC, 58 cm
Sykehuset i Østfold

SCC, 58 cm
Dissing
Curing membrane
Grinding
Coating
• Grinding
• Coating
HOW TO CONTROL THE RELATIVE HUMIDITY IN THE CONCRETE?

"Normal" concrete and desiccation
• RF must be measured according NS 3511:2014

«Self-desiccation» concrete
• Documentation on each concrete mix, NB15 Gulv på grunn
Dokumentation of self-desiccation
Pb. 15: Gulv på grunn (Concrete floor on ground)

• Self-desiccation of concrete mixes must be after prosedure in NB15
• Self-desiccation is documented by measuring relative humidity:
  • ≤ 85% after 1 år and/or
  • ≤ 80% after 2 år
### Table 1: The 27 products in the family of common cements

<table>
<thead>
<tr>
<th>Main types</th>
<th>Notation of the 27 products (types of common cement)</th>
<th>Composition [proportion by mass$^1$]</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEM I</td>
<td>Portland cement</td>
<td>Fly ash</td>
</tr>
<tr>
<td></td>
<td></td>
<td>calcareous</td>
</tr>
<tr>
<td></td>
<td></td>
<td>burnt shale</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Limestone*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Minor additional constituents</td>
</tr>
<tr>
<td>CEM I</td>
<td>Portland cement</td>
<td>W</td>
</tr>
<tr>
<td></td>
<td>CEM II/A-S</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>CEM II/A-D</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Portland-silica fume cement</td>
<td>80-94</td>
</tr>
<tr>
<td></td>
<td>Portland-pozzolana cement</td>
<td>65-79</td>
</tr>
<tr>
<td>CEM II</td>
<td>Portland-fly ash cement</td>
<td>80-94</td>
</tr>
<tr>
<td></td>
<td>CEM II/A-V</td>
<td>65-79</td>
</tr>
<tr>
<td></td>
<td>Portland-burnt shale cement</td>
<td>80-94</td>
</tr>
<tr>
<td></td>
<td>Portland-limestone cement</td>
<td>65-79</td>
</tr>
<tr>
<td></td>
<td>Portland-composite cement</td>
<td>80-94</td>
</tr>
<tr>
<td>CEM III</td>
<td>Blastfurnace cement</td>
<td>35-64</td>
</tr>
<tr>
<td>CEM IV</td>
<td>Pozzolanic cement</td>
<td>65-89</td>
</tr>
<tr>
<td>CEM V</td>
<td>Composite cement</td>
<td>40-64</td>
</tr>
</tbody>
</table>

**Note:**
- W, T, L, LL represent various proportions of materials.
- CEM I is standard Nordcem Industri Anlegg Sr. Embra Standard Rapid.
<table>
<thead>
<tr>
<th>Main types</th>
<th>Notation of the 27 products (types of common cement)</th>
<th>Composition [proportion by mass]</th>
<th>Main constituents</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEM I</td>
<td>Portland cement</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CEM I</td>
<td>95-100</td>
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<td></td>
<td>Portland-slag cement</td>
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<td>80-94</td>
</tr>
<tr>
<td></td>
<td>CEM II/B-S</td>
<td>65-79</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Portland-silica fume cement</td>
<td>CEM II/A-D</td>
<td>90-94</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Portland-pozzolana cement</td>
<td>CEM II/A-P</td>
<td>80-94</td>
</tr>
<tr>
<td></td>
<td>CEM II/B-P</td>
<td>65-79</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CEM II/A-Q</td>
<td>80-94</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CEM II/B-Q</td>
<td>65-79</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Portland-fly ash cement</td>
<td>CEM II/A-V</td>
<td>80-94</td>
</tr>
<tr>
<td></td>
<td>CEM II/B-V</td>
<td>65-79</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CEM II/A-W</td>
<td>80-94</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CEM II/B-W</td>
<td>65-79</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Portland-burnt shale cement</td>
<td>CEM II/A-T</td>
<td>80-94</td>
</tr>
<tr>
<td></td>
<td>CEM II/B-T</td>
<td>65-79</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Portland-limestone cement</td>
<td>CEM II/A-L</td>
<td>80-94</td>
</tr>
<tr>
<td></td>
<td>CEM II/B-L</td>
<td>65-79</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Portland-composite cement</td>
<td>CEM II/A-M</td>
<td>80-94</td>
</tr>
<tr>
<td></td>
<td>CEM II/B-M</td>
<td>65-79</td>
<td></td>
</tr>
<tr>
<td>CEM II</td>
<td>Blastfurnace cement</td>
<td>CEM III/A</td>
<td>35-64</td>
</tr>
<tr>
<td></td>
<td>CEM III/B</td>
<td>20-34</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CEM III/C</td>
<td>5-19</td>
<td></td>
</tr>
<tr>
<td>CEM IV</td>
<td>Pozzolanic cement</td>
<td>CEM IV/A</td>
<td>65-89</td>
</tr>
<tr>
<td></td>
<td>CEM IV/B</td>
<td>45-64</td>
<td></td>
</tr>
<tr>
<td>CEM V</td>
<td>Composite cement</td>
<td>CEM V/A</td>
<td>40-64</td>
</tr>
<tr>
<td></td>
<td>CEM V/B</td>
<td>20-38</td>
<td></td>
</tr>
</tbody>
</table>

I Norge i år 2016

Norcem Industrisement CEM I 42,5 R
Cemex Rapid
Cemex Hvit
Aalborg Rapid
Aalborg White
CEM I 52,5 N - (LA)
CEM I 52,5 R – SR5
Cemex Miljosement CEM II/B-S 52,5 N

Norcem Anlegg FA CEM II/A-V 42,5 N
Norcem Lavkarbonsement CEM II/A-V 42,5 N
Norcem Standard FA CEM II/B-M 42,5 R.

Cemex Miljosement II CEM III/A 42,5 N
Cemex LH LC* CEM III/B 42,5 N
NB 37 Lavkarbonbetong

<table>
<thead>
<tr>
<th></th>
<th>B20 M90</th>
<th>B25 M90</th>
<th>B30 M60</th>
<th>B35 M45/MF45</th>
<th>B35 M40/MF40</th>
<th>B45 M40/MF40</th>
<th>B55 M40/MF40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lavkarbon A</td>
<td>170</td>
<td>180</td>
<td>200</td>
<td>210</td>
<td>230</td>
<td>240</td>
<td>250</td>
</tr>
<tr>
<td>Lavkarbon B</td>
<td>200</td>
<td>220</td>
<td>240</td>
<td>270</td>
<td>300</td>
<td>310</td>
<td>320</td>
</tr>
<tr>
<td>Lavkarbon C</td>
<td>240</td>
<td>260</td>
<td>280</td>
<td>320</td>
<td>350</td>
<td>360</td>
<td>370</td>
</tr>
<tr>
<td>Bransjereferanse</td>
<td>280</td>
<td>300</td>
<td>320</td>
<td>370</td>
<td>410</td>
<td>420</td>
<td>430</td>
</tr>
</tbody>
</table>

Maksimalt tillatt klimagassutslipp [kg CO₂-ekv. pr m³ betong]

Klimagassutslippet oppgis for 1 m³ betong og dekker livsløpet fra råvareuttak til betongprodusentens fabrikkport. Utslippet oppgis som kg CO₂-ekv./m³ betong. Ved omregning fra kg/m³ til kg/tonn brukes densiteten 2400 kg/m³.
Admixtures, water reducers

Water reduction:

1. generation
   10%
   Lignosulphonates
   (Gluconates)
   1930 - 1940

2. generation
   20%
   Naphtalene
   1970
   Melamine
   1980

3. generation
   40%
   Polycarboxylates
   Copolymer
   1990 - 2000
Exposure classes

XC: Carbonatisation
XD: Deicing salts
XS: Salt from sea
XF: Frost
XA: Chemikals
## Durability Classes (Bestandighetsklasser)

### Table NA.15 – Selection of durability class, depending on exposure class

<table>
<thead>
<tr>
<th>Exposure Class</th>
<th>M90</th>
<th>M60</th>
<th>M45</th>
<th>MF45</th>
<th>M40</th>
<th>MF40</th>
</tr>
</thead>
<tbody>
<tr>
<td>X0</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>XC1, XC2, XC3, XC4, XF1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>XD1, XS1, XA1, XA2&lt;sup&gt;a&lt;/sup&gt;, XA4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>XF2, XF3, XF4</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>XD2, XD3, XS2, XS3, XA3&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>XSA&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**

- XA2, XA3, or XSA may be used for contact with sulfate in concentrations higher than those specified for XA2. The sulfate-resistance requirement in the specification must be met, and it may be required that sulfate-resistant binders (SuR1 or SuR2) be used. See also Table NA.13.
- For construction purposes, only XA2, XA3, or XSA can be used for exposure to sulfate. The sulfate-resistance requirement in the specification must be met, and it may be required that sulfate-resistant binders (SuR1 or SuR2) be used. See also Table NA.13.
All construction under ground is v/c-ratio 0,4
Because of parking areas
Building moisture

Building Technology Regulations (TEK17) require materials to be sufficiently dry during incorporation to prevent hygienic problems such as mold growth or chemical degradation.
Other advantages by using a low v/c-ratio?

Edge lofting (kantreising)
Shrinkage

Tid, dager

Svinn, \((10^{-6})\)

B30M60

B45M40

Drying shrinkage

Autogent shrinkage
Edge lofting (kantreising)
Edge lofting (kantreising)

• The surface dries out and contract
  • The concrete crumbles
• 1-2 m from edges or corners
• Can be reduced by
  • Thicker floor
  • Reinforcement
  • More covering of the concrete, slower drying
  • Lower v/c-ratio

• «MIGHT» be less after some years, when the concrete is «dry» (1-5år)
Rehabilitation of bathrooms

- AF started in 1999
- From 2002:
  - 800-1400 bathrooms/year
- Special mortar for bathrooms in 2006
Rehabilitation of bathrooms
TM Støpemørtel Bad

Trondheim Mørtelverk produced TM Støpemørtel Bad for AF.

- Mortar B35M40 – «dry»
- v/c-ratio 0,37
- Standard FA-iment
- Melamin (SP)

If the water-ratio happened to be 0,39, the mortar was impossible to process, difficult for the craftsman.
TM Støpemørtel bad

Trondheim Mørtelverk prodused TM Støpemørtel Bad for AF.

- Mortar B35M40 – «dry»
- v/c-ratio 0,37
- Standard FA-sement
- Melamin (SP)

Grading curve
Weber is still selling this mortar:

Quick hardening and Self-desiccation
We developed also a shrinkage compensated mortar with TM

**PRODUKTFORDELER**
Selvtørrkende, svinnkompensert mørtel som kan belegges tidlig.

Self-desiccation, shrinkage compensated
Self-levelling floors (Avrettingsmasse)

3 types

• Gypsum
  • Bind 18 % vann

• Portlandcement
  • Bind 23 % chemical og 18 % physical (using 40 %)

• “Specialcement”, different types together
  • Aluminat, sulfoaluminat, portland, gips
  • Bind from 18 % and above
Self-levelling floors, desiccation

3 guiding principles

- «Normal»: drying 1 cm pr. uke
- «Quick»: drying 1 cm pr. dag
- «Selv-desiccation»: ?
Gypsum: 1 cm pr. week

Thickness 30 mm
RH in air: 60-80 %
Temp. i air: 20 - 23 oC
Cement-based: 1 cm pr. week

Thickness: 30 mm
RH i air: 20-45 %
Temp. i air: 17 - 23 °C
Quality on the surface has importance

Gypsum

Cement based
Self-desiccation self-levelling floors
TAKK FOR OPPMERKSOMHETEN

Bernt Kristiansen
AF Gruppen
Self-desiccation by the use of shrinkage reducing agents and other additives
About the project

- The partners were:
  - Skanska (Contractor)
  - Norcem (cement producer)
  - NorBetong (concrete producer)
  - Sika (additives)
  - UCO Utleiecompagniet (RBK-measurements)

- The project period: 2013 – 2016

- Measurement methods and instruments that were used:
  - RH with the Swedish RBK method with Vaisala and “Byggforsk” method with protimeter
  - Shrinkage test

*474.531 Fuktmålinger i bygninger. Instrumenter og metoder*
Scope

- Are concretes with low w/c-ratios self-desiccating?
- Does fly ash influence the self-desiccation effect?
- Do SRA influence the self-desiccation effect?

- The concrete that was studied
  - w/c = 0,39
  - Norcem Cements used; Industri, Standard FA, Anlegg FA, Lavkarbonsement
  - Two shrinkage reducing agents (SRA); Sika Control-50 and Mapecrete SRA-N
Method

- Cylinders were cast in closed containers and closed with epoxy
Method

- 3 samples for each concrete mix
- To different measurement methods
  - RBK with Vaisala
    - Calibration and validation according to the RBK method performed by RBK-certified personnel
  - SINTEF with Protimeter
    - Validation at 85 % RH at 20°C
    - Validation at 75 % RH at 20°C

Samples with D=110 mm and H=130 mm.
- The samples were stored in our office archives.
## Concrete mixes

<table>
<thead>
<tr>
<th>Name</th>
<th>$v/(c+\Sigma kp)$</th>
<th>Cement</th>
<th>Cement [kg/m³]</th>
<th>Fly ash</th>
<th>Silika</th>
<th>SRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Industri</td>
<td>0,39</td>
<td>Industrisement</td>
<td>475</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2. Std. FA</td>
<td>0,39</td>
<td>Standard FA</td>
<td>450</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3. Anl. FA</td>
<td>0,39</td>
<td>Anlegg FA</td>
<td>395</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4. Tilsatt FA</td>
<td>0,39</td>
<td>Anlegg FA</td>
<td>360</td>
<td>9 %</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5. SRA Sika</td>
<td>0,39</td>
<td>Anlegg FA</td>
<td>395</td>
<td>-</td>
<td>-</td>
<td>1,5%</td>
</tr>
<tr>
<td>6. SRA Mapei</td>
<td>0,39</td>
<td>Anlegg FA</td>
<td>395</td>
<td>-</td>
<td>-</td>
<td>1,5%</td>
</tr>
<tr>
<td>7. Høyfast</td>
<td>0,35</td>
<td>Anlegg FA</td>
<td>415</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>8. Høyfast + Tilsatt FA</td>
<td>0,35</td>
<td>Anlegg FA</td>
<td>388</td>
<td>9 %</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>9. Tilsatt Silika</td>
<td>0,39</td>
<td>Anlegg FA</td>
<td>365</td>
<td>-</td>
<td>4 %</td>
<td>-</td>
</tr>
<tr>
<td>10. Tilsatt Silika og FA</td>
<td>0,39</td>
<td>Anlegg FA</td>
<td>340</td>
<td>9 %</td>
<td>4 %</td>
<td>-</td>
</tr>
<tr>
<td>11. Lavkarbon</td>
<td>0,39</td>
<td>Lavkarbonsement</td>
<td>450</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Anlegg FA=CEMII/A-V, Standard FA=CEMII/B-M, Industri = CEMI, Lavkarbonsement=CEMII/B-V
Concrete mixes

<table>
<thead>
<tr>
<th>Name</th>
<th>$\nu/(c+\sum kp)$</th>
<th>Slump [mm]</th>
<th>Slump flow [mm]</th>
<th>28-days strength [MPa]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Industri</td>
<td>0,39</td>
<td>220</td>
<td>350</td>
<td>66,7</td>
</tr>
<tr>
<td>2. Std. FA</td>
<td>0,39</td>
<td>240</td>
<td>480</td>
<td>69,1</td>
</tr>
<tr>
<td>3. Anl. FA</td>
<td>0,39</td>
<td>210</td>
<td>370</td>
<td>75,8</td>
</tr>
<tr>
<td>4. Tilsatt FA</td>
<td>0,39</td>
<td>220</td>
<td>390</td>
<td>76,4</td>
</tr>
<tr>
<td>5. SRA Sika</td>
<td>0,39</td>
<td>240</td>
<td>480</td>
<td>75,5</td>
</tr>
<tr>
<td>6. SRA Mapei</td>
<td>0,39</td>
<td>240</td>
<td>540</td>
<td>73,3</td>
</tr>
<tr>
<td>7. Høyfast</td>
<td>0,35</td>
<td>250</td>
<td>640</td>
<td>89,8</td>
</tr>
<tr>
<td>8. Høyfast + Tilsatt FA</td>
<td>0,35</td>
<td>240</td>
<td>570</td>
<td>78,3</td>
</tr>
<tr>
<td>9. Tilsatt Silika</td>
<td>0,39</td>
<td>230</td>
<td>470</td>
<td>78,5</td>
</tr>
<tr>
<td>10. Tilsatt Silika + FA</td>
<td>0,39</td>
<td>230</td>
<td>580</td>
<td>78,3</td>
</tr>
<tr>
<td>11. Lavkarbon</td>
<td>0,39</td>
<td>245</td>
<td>560</td>
<td>57,9</td>
</tr>
</tbody>
</table>

- The target slump was the same in all recipes.
Results with «Byggforsk»

- Each bar is the average of three measurements.
Results with «Byggforsk» and «RBK»
The samples were weighed in order to correct the RH for the ambient moisture loss using a suitable desorption-isotherm and Power’s model.
Results with moisture loss
Results with moisture loss

- **v/c = 0.39**
  - 20% FA

- **v/c = 0.35**
  - 20% FA

- **v/c = 0.35**
  - 30% FA
1. The concrete mixes with blended cements and added fly ash have a reduced self-desiccation effect on short term (~3 months).

2. All concrete mixes showed self-desiccation effect after one year, and significant effects after three years.

3. SRA do not affect the self-desiccation significantly on long term.
Fuktmätning i betong

Varför
Var
Hur
När

Polygon/AK

- 20 RBK-auktoriserade (mest HumiGuard i borrhål)
- Diplomerade fuktssakkunniga
- Fuktåktsansvariga produktion
- Eget analyslab för bl.a. GBR-mätning
- Forcerande torkteknik
- Fuktskadeutredare

Golvsystemet
Hela fuktkedjan behöver fungera

Fukt i systemet

Limfukt 0-150g/m²
Avjämning 100g/kg/m²
Betong tiotals kg/m²

Självuttorkning och ångtät Limfukt ger skada!!!

Ångöppen betong med viss självuttorkning

Självuttorkande och ångtät
Limfukt ger skada!!!
Limfukt torkar snabbt
Vissa risk kvar vid omfördelning!

Ångöppen avjämning
Skada om avjämning inte får torka!!!

Ångöppen betong
< 0 + limfukt -

Beslutsunderlag för läggning
< 0 + limfukt -
Bedömningsuderlag RBK + ?

Visuell rimlighetsvärdering underlättar!

Ibland blir det helt orimligt!
Vi har hittat och hittar "orimliga" mätresultat

Har vi rätt fokus? GBR-mätning är lika viktigt!

Rekommendationer

- Verifiera självuttorkning
- Måt i avjämning enligt GBR
- Spåra torkmiljön, den behöver styras
- Avjämnna tidigt så att det hinner torka
- Trendmät tidigt efter torkstart för att hinna justera vid behov
Frågor?

Golvsystem med låg risk

Bild: Husbyggaren
130 tillfrågade skadeutredare, erfarenhet de senaste 5 åren

Vår bedömning av skaderisken med ångtäta ytor

Ångtäthet i mattor

Vår bedömning av skaderisken med ångöppna ytor

Ångtäthet i betong

Omfördelning under matta

Rekommendationer för golvomgivning samt underlag för golvbeläggning
Kan vi enas kring situationer blir det lättare att orientera sig
Torrhalt och limmängd har betydelse!

Limfukt - hur torr/tjock avjämning? Torr vid klistring!

**Table 2. Adhesives tested in Sweden on function of gluing PVC, Limed and unlimed.**

<table>
<thead>
<tr>
<th>Gluing Method</th>
<th>PVC Tested</th>
<th>Limed</th>
<th>Unlimed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method 1</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Method 2</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Method 3</td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
</tbody>
</table>

Figure 5. - Impact of liming compound A. Data are measured values.

**Brancherformulering för limning av MFK-beläggning av plastglad av PVC på sprödpapper.**

<table>
<thead>
<tr>
<th>MFK content</th>
<th>PVC content</th>
<th>Limed</th>
<th>Unlimed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
</tr>
</tbody>
</table>
### Placering av spärrar

<table>
<thead>
<tr>
<th>Tät matta</th>
<th>Limfukt</th>
<th>Alkalispärr närmast lim</th>
<th>Fuktspärr under avjämning</th>
<th>Fuktspärr under avjämning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Betong RF</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Rekommendationer

- Ångöppna golvytor ger stor risksänkning
- Avjämningens uttorkning och tjocklek behöver fukt säkerhetsprojekteras mht limfukt smängd
- Det är ofta smart att avjämma tidigt
- Spärrar behöver fukt säkerhetsprojekteras

Vi behöver hjälpas åt att skapa och sprida fakta
Tack och lycka till med fuktsäkerheten
A list of previous and upcoming Nordic workshops is available on www.nordicconcrete.net