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Sensor for the determination of residual moisture in cement screed constructions

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1 ABSTRACT

A system compatible sensor for the detection of residual moisture in cement screed or concrete was developed as an alternative or addition to the standard of DIN EN 13318 approved methods (calcium carbide and gravimetric methods). Continuous measurements can be made available during the exsiccation which will allow a prediction of surface readiness. Repetitions of measurements are also viable in the same location without vibration or local destruction as well as moisture in varying depths can be assessed simultaneously. Due to its technology of textile fabrication sensors are inexpensive. Thus, several sensors can be placed at preselected locations.

2 INTRODUCTION

Wetness and moisture are the main reasons for various defects in building structures in the past and today. A new kind of sensor detecting residual moisture in hardening screed or concrete has been developed.

Sources for moisture impact are:
- surrounding areas (earth contacted structures, ceilings)
- residual moisture in surrounding structures (concrete walls or ceilings)
- inner moisture of screed mixture
- water inside the structure (diffusion through wooden ceilings)
- condensed water due to use of the rooms (bathroom)
- moisture impact by leaks or wet weather

As a result, limitations are given for the floor finishes such as coatings or coverings, which determine the residual moisture in a low cost and easy way, for example in cement screed constructions. These facts show that it is necessary to survey moisture to ensure high quality and durability of building structures and to avoid moisture caused damages. The detection of these damages is a not comprehensively unfixed problem till today because approved methods are based on local destructions. By state of the art there are no non-destructive methods reliable and accepted assessing residual moisture to avoid consequential losses (like early coating, masking, covering). Most of the international science articles include studies of the chemical behaviour of concrete against corrosion by the evaluation of electrical conductivity.

In research, a new sensor with an associated reading instrument has been developed which is easy to install.

3 STATE OF THE ART

In Europe screed is defined in DIN EN 13318 as "layer or layers of screed material laid in situ, directly onto a base, bonded or unbonded, or onto an intermediate layer or insulating layer, to obtain one or more of the following purposes:

– to obtain a defined level;
– to carry the final flooring;
– to provide a wearing surface."

Screed material is a composition of a comprising binder, aggregates and possibly liquids to ensure the setting of the binder and in some cases admixtures and/or additives. Aggregates are granular particles for example: sand, crushed rocks, gravels. Particles smaller than 63 µm are called filler. The composition is called "mortar" if aggregates are less than 4 mm in diameter and "concrete" above this level. In Europe in average 70 % of all screeds are cementitious based. Several kinds of screed are available including bitumen emulsion cement screed, cementitious screed, polymer modified cementitious screed, magnesite screed, synthetic resin screed, calcium sulfate screed as well as mastic asphalt screed [DIN EN 13318].

Screed types premixed with water have to dry and harden before being ready to cover. The process of drying lasts about four weeks (28 days). This mainly depends on substitution of room air, temperature as well as relative and absolute humidity. In practise, it is a hard to control the process. The whole moisture content is the key criterion of the quality of the flooring structure. So the determination of moisture and the compliance of the limited values of all water based screeds are definitely required.

At present, only two methods are permitted to determine residual moisture. The most popular method of moisture detection is the CM-method (CM= Calcium carbide Method), based on the chemical reaction of water and calcium carbide. The second approved method is the gravimetric method which requires time and energy to dry the samples.

Whilst approved both methods include disadvantages, too:
- no reproducibility (measurements cannot be repeated at the same location)
- continuous or long-term measurements are rarely achievable
- no measurements of different concrete horizons
- destructive sample preparation possible, vibrations and noise
- sample preparation and the evaluation of local measurements requires special knowledge

There are many methods available to determine moisture, but only few of them are used by building construction industries. The infrared thermograph procedure in particular reveals the different zones of moisture. Measurements of electrical resistance and capacitance are common methods to localise the moistest areas. Many instruments are available determining internal moisture due to an external measurement on the surface of the screed. These instruments are suitable to localise moisture. They are not competent to get values according to the CM-method.

4 DEVELOPMENT OF SENSOR LAYOUT FOR CAPACITIVE MEASUREMENT

The use of an electrical field is most appropriate from several available methods measuring residual moisture inside cement screed in the setting and the subsequent hardening period. To evaluate the reliability performance of the capacitive sensor method the verification of different dielectrics between the electrodes got usable data. Tests with different embedded sensors and following different kinds of screed have been realised by employing the new developed reading instrument.

Furthermore, sensors embedded in screed of divergent moisture and thus varying chemical resistance for a long time use behind the stage of cover has been tested. In addition, various new basic materials were tested without loose the mechanical characteristics regarding to the reduction of the sensor dimensions for the efficient automatic manufacturing.

The aim was to develop a practicable measuring method with easy to use components. The method has to be reasonable in manufacturing and also in use to generate application in masses and effectually minimise the risk of failure measurements.

4.1 General design

In interdisciplinary cooperation between scientists of the Professorship of Lightweight Structures and Polymer Technology (SLK), the Professorship of Circuit and System Design (SSE) and the Competence Centre of Lightweight Structures (SLB) developed the Direct-Material-Control-(DMC)-system based on resin embedded embroidered sensors. This textile technology based sensor is a component of a distinguished composite structure and generates signals such as material deformation, humidity and temperature. The new screed sensor is built up from a carrier structure, a contact or later transmitting module and a textile base with an embroidered wire sensor. The physical principle of the measurement is capacitive. After application the sensors remain in screed forever.

4.2 Sensor layout and stitch base

A lot of analyses are necessary to find the optimal layout of the embroidered sensor, the base material and the wire of the electrode. Basic data have been vector graphics for the stitching process, which are transferred via software to the machine. Most important was the input of the specific machine data like stitch distance and logical sequences. Finally nonwoven fabric polymers as a basis for the embroidered sensors have been tested best preliminarily for suitability, disposability and costs. A copper wire, the chosen wire material for the stitching, was applied by the Taylored Fibre Placement-Method. Before finishing and embedding, the sensors get a check after contacting a measuring line.

The sensitive textile based sensors need to be adapted to fit the rough conditions of the building site. Sensor protection and easy handling for a stabilised application into screed is realised by covering with a carrier of a mineral coating. Sensors should be also adaptable for different screed thicknesses (Figure 1).

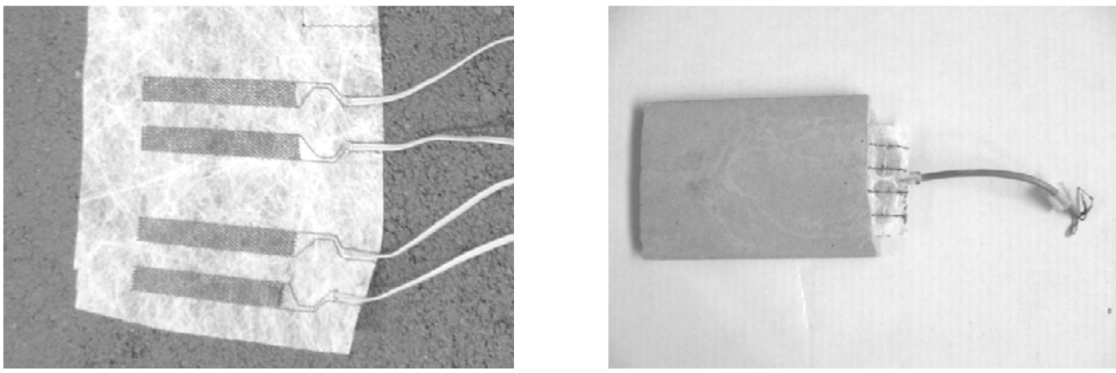

Figure 1. Embroidered sensor and sensor in carrier.

4.3 Installation into screed

After the application of sensors into the screed the bonding between surrounding material and stitch base as well as between cover materials and screed is very well. There was no interface influencing the dielectric properties negatively. Principally, the sensor module should not visible in the screed. In contrast, a solid connection with the reader by a wire with the contacting platform is of central interest. To place upright at first the electrical connections have been laid sideways and for the final design again on the head of the electrodes to complete with the plug and the plastic protecting tube. A second afresh prototype includes the protecting tube itself (Figure 2).

Figure 2. Sensor prototype with plastic tube and included tube

There are no differences if the sensor is in upright or inclined position, for instance after the following power-floating process of the surface. Inclinations from 0° up to 45° have shown no remarkable variances. The drying process has been immediately observed by the new associated measuring equipment. The CM-method or gravimetric methods have been used to provide a comparison giving a further opportunity to calibrate the electronic equipment for more measurements.

Test series have been performed for three years and with regard to the durability sensors do not show any signs of destructions or wear-out in an alkaline background after longer time.

4.4 Procedure of measurements

The capacitive measurement is dependent on the dielectric properties of the adjacent material whereby an electrical field is identified always between two electrodes. For instance it relates the field 1/2, which is between electrode one near surface and electrode two next deeper (see Figure 5). With the aid of an electronic hand held device data are taken and displayed. It is possible to obtain data at various horizons to detect the moisture zonation or alternatively an average value within the reader's range similar to the CM-Method. In addition it is also possible to predict the progression of drying by continuous readings which will support further actions as well as the usage of drying machines.

5 APPLICATION OF THE SENSOR

5.1 Sensor and measurement device

For the practical application of the textile based moisture sensors the sensor module (Figure 3) is a flat device and will placed without additional supports upright in situ into fresh stiff or plastic screed. The plug is situated on the top edge in a protection tube. A little flag of the tube lid marks the sensor's position. It has to be removed before the floor finishes are applied. The reading device provides the power supply and a two row display for data (Figure 4). By choice it displays also local temperature and humidity near the instrument. That data is a mandatory knowledge to assess the absorbing capacity of the room air above the screed as well as the drying fine.

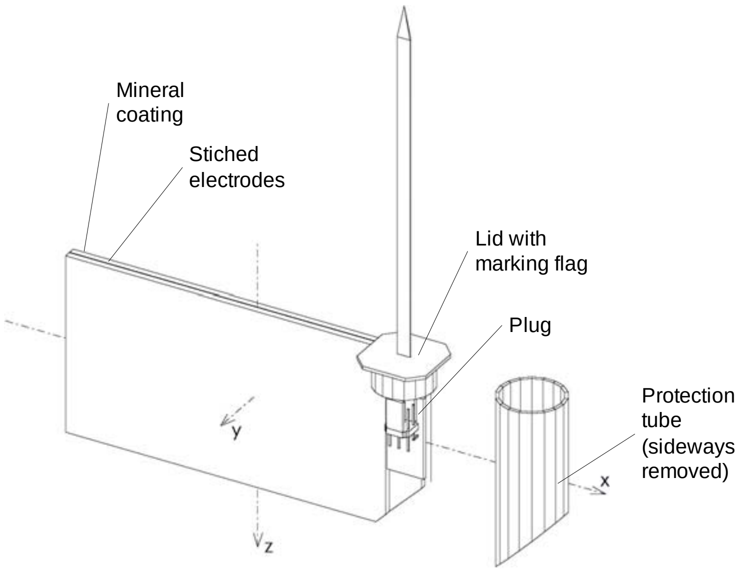

Figure 3. Diagram of a sensor.

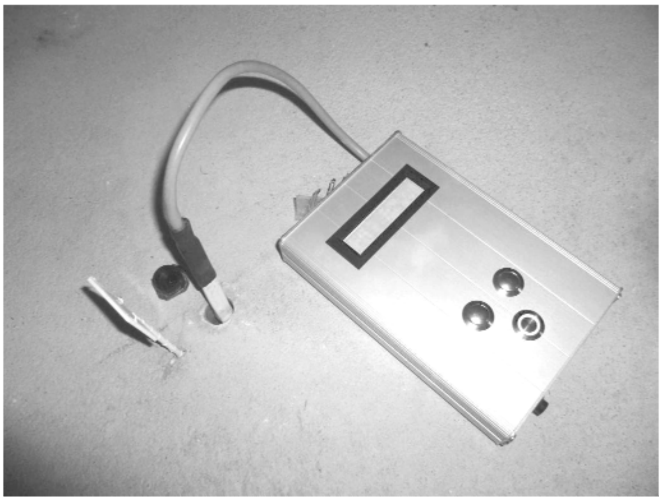

Figure 4. Reader device (prototype) plugged in.

5.2 Installation

A series of tests regarding handling, installation time as well as installation quality has been continued by further onsite tests by laying contractors. A cut in fresh screed is required before the sensor module is inserted, follow by a gentle manual pressing at both sides to fix the module as well as closing the gaps in the screed. Just the cap with flag will be left exposed once the power floating is finished. Removing the cap will allow to plug in the measuring instrument when required. Otherwise the screed is ready to cover.

5.3 On site tests

Tests for the applicability of the new textile based sensors were adopted under building site related conditions (aggregates stored in open air, used screed pump machine, installation by qualified screed contractors, uncontrolled room climate) in cooperation with the research partner Unger Bausysteme GmbH. They have been observed by the architect and building expert Dankhard Remmler. Measurements with both CM-method and sensor have been undertaken parallel recording the progression of the drying process. The sensor's data allowed a more precise adjustment presented in CM-% (Figure 5) for the measuring instrument. The test was repeated on different building sites. Recording the progressions of drying in the test room will minor variously by comparison to data obtained from CM-method. Each test allowed to predict the date when the minimum residual moisture would be achieved. Hence, a new textile based sensor system to determine moisture in screed constructions is available.

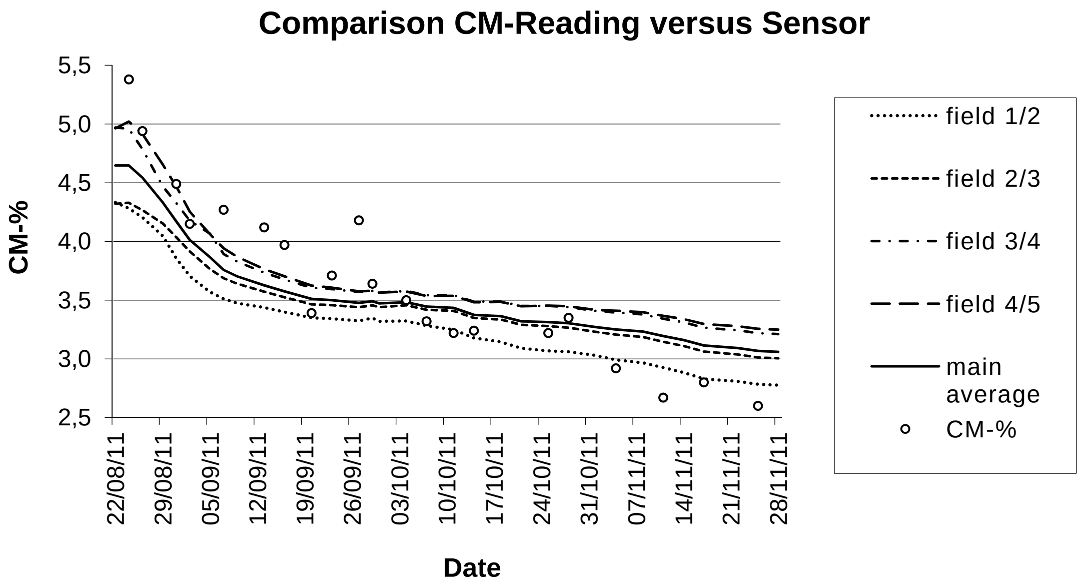

Figure 5. Example for the relation between the values of the CM-method and the indicated value of the sensor fields.

Table 1. Comparison of CM-, gravimetric -method and sensor method.

	CM-method	Gravimetric method	Sensor method
Place of measurement	variable	variable	Installation layout before screed works
Mechanical stress on Screed	destructive	destructive	non destructive
Duration	approx. 30 min	minimum 24 h	instant
Qualified staff	required	required	not required
Reading	local to sample	local to sample	area of installation
Reading accuracy	depends on realising staff	depends on realising staff	independent
Measurement results	in CM-%	in weight-%	optional in CM-% or weight-%

6 SUMMARY

The development of the new sensor to determine moisture allows a non-destructive snapshot of the residual moisture in screed. Hence, an easygoing low effort possibility to record continuous data is available and this allows a prediction of the drying tendency and fine. The measuring is cost efficient, requires a minimum of time and no special staff. The reading inside the material is of adequate accuracy and exposes additional data in different horizons. The carrier of the sensors is applicable with a planned further transmitting unit. Thereby, the sensors could upgrade with advance electronic and network in a next step.

The Sensors have been developed for an assessment of the screed area. Reasonable planning is required to locate the sensors before the screed is installed. Moreover the sensor method cannot replace the required quality management to inspect the works because it does not detect surface irregularities outside the surrounding area of sensors, such as collapsed liquid buckets, leaks of flexible tubes, water puddles especially near disassembled heaters, leak pipes inside the screed, as well as local leakage in veneer and roof. The sensors can be reactivated to detect moisture in case of damages to improve further actions.

Under realistic constructive conditions the sensor measurement in combination with CM-method is an excellent option to make better decisions during the drying process, for acceleration of drying or drying in several rooms and to estimate the right time for flooring. The sensor measurement already is more economic if only one second CM-measurement in same room is needed.

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