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Original Research Article

ACCURACY OF THE CM CARBIDE METHOD WHEN TESTING COUNTER-FLOORS USED IN THE CONSTRUCTION INDUSTRY

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A b s t r a c t

Special requirements are placed on finishing materials and foundations for these materials. The technical datasheets for wooden floors contain detailed moisture guidelines regarding counter-floors for these materials. To check the moisture level, the carbide method (CM method) is recommended by manufacturers and many specialists. The authors of the paper performed moisture tests for various counter-floors (anhydrite and cement jointless floors, cement-sand mixtures) using the direct gravimetric (laboratory) method and the carbide method. Test results were collected and analyzed.

Keywords: moisture test, moisture, CM method, carbide method, floors, counter-floor, jointless floor

1. INTRODUCTION

Due to the increasing pace of erecting and finishing construction objects, materials used in the construction industry are subjected to an increasingly technological regime. Materials intended for use in construction must meet a number of requirements and criteria. In addition to direct requirements for specific products, requirements are also made for materials that directly affect the input materials (underlay). A very good example is plaster or counter-floors

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as direct layers for finishing materials. Manufacturers of finishing materials often protect themselves by writing down the requirements for undercoating materials in their product datasheets. This is, among others, the case for cement and anhydrite jointless floors which are counter-floors for wooden glued floors.
Technical datasheets and assembly instructions contain entries regarding the maximum absolute moisture of the counter-floor (e.g. 12). Most manufacturers suggest a method for performing tests and measurements, some of which require the CM carbide method as an accurate and reliable measurement. The authors of the paper, during many years of work on expert opinions, have met with very different views regarding the application of this method and the accuracy of its results 4 5. The publication presents the humidity tests of the most commonly used jointless floors in the construction industry and compares the real moisture of materials with the moisture obtained by the CM method in variants with different types of counter-floors (cement, anhydrite) and different moisture values (in the range of 2.0 - 14%).

2. MOISTURE TESTS

In order to determine the moisture content of structural elements and finishes, it is necessary to conduct appropriate tests. Moisture tests are divided into two basic groups being direct measurement and indirect measurement.
The direct (laboratory) measurement is considered to be the only reliable way to measure moisture. However, laboratory moisture tests have a number of limitations related primarily to costs, time to obtain results, and the need for often quite deep interference with a partition or test item. The method of performing moisture determination is specified in the standards 12.
However, in many cases, it is difficult or even impossible to collect the material for testing (testing in historic buildings, below the finishing layers). Measurements using indirect moisture testing methods, therefore, become an alternative in such situations.
Indirect measurement is a measurement whereby results are obtained on the basis of direct measurement of other quantities, based on the known relationship between these quantities and the measured quantity. The division of the indirect methods for testing material moisture is as follows: chemical methods; carbide, Karl-Fisher's, indicator papers, and physical methods; electrical (microwave, dielectric, resistive), non-electric (extractive, nuclear, nuclear magnetic resonance, based on the balance of the vapor partial pressures, based on measurement of thermal properties).
In reality, only a few methods are used for in-situ research. The most important of these are dielectric, resistive, microwave, and carbide. Other methods are of more theoretical than practical significance.

Tab. 1. Division of the moisture determination methods

Type of method	Method name	Parameter measured
Chemical method	indicator method	change in the color of the indicator paper due to the material moisture
	carbide method (CM)	pressure of acetylene (resulting from the reaction of carbide with water) in a hermetic chamber
Physical methods, electrical	resistive method	change in the electrical resistance due to the change in moisture
	microwave method	attenuation of microwaves passing through a moist material
	dielectric method	change of the dielectric constant of a material as a result of a moisture change
Physical methods, nuclear	neutron method	the number of slowed neutrons caused by the collision with hydrogen atoms
	X-ray method	change in the X-ray radiation intensity after passing through the material tested

3. CARBIDE METHOD TESTS - CM

One of the most popular methods for indirect testing of moisture is the chemical method – carbide. The collection of material should be done with a hammer or cutter rather than using power tools, to avoid drying the sample during collection. The hole should cover approx. 2/3 of the partition thickness and the top layer should be omitted. The material so obtained should be crushed so that the maximum dimension of the material is 2 mm.

Then, a specific weight of the collected material and calcium carbide (carbide) are introduced into a sealed steel vessel equipped with a pressure gauge. Measuring sets with ampoules containing ready-made weights of calcium carbide are also available. When the vessel is shaken, the ampoule breaks down and the contents are mixed. The reaction occurs according to the formula:

$$CaC_2 + 2H_2O \Rightarrow C_2H_2 + Ca(OH)_2 \tag{3.1}$$

causing the release of acetylene and increasing the pressure in the cylinder, which value is determined after some time. The sample moisture corresponds to the pressure created and can be read from the table attached to the device. In newer devices, the sample mass of the material tested, the measuring range of the manometer, and the dimensions of the measuring chamber have been selected so that the manometer is scaled directly in percentage of relative moisture.

3.1 Experimental research

In order to check the accuracy of the carbide measurements, a number of jointless floor materials and cement-sand mixes were tested. The moisture results obtained by the CM method were compared with the moisture results obtained by the gravimetric method in accordance with 12.
The research was conducted as follows:

Selection of materials for the study

The samples were made of the most common materials used in flooring. These were counter-floors made of anhydrite and cement jointless floors, and cement-sand mixtures.
Types of flooring materials taken for testing:

- Anhydrite jointless floor with 35MPa strength – marked hereinafter as JA1,
- Anhydrite jointless floor with 28MPa strength – marked hereinafter as JA2,
- Cement jointless floor with 20MPa strength – marked hereinafter as JC1,
- Cement jointless floor with 25MPa strength – marked hereinafter as JC2,
- Cement-sand mixture with proportions per 0.1 m^3: 25kg of a 32.5 cement, 20l of water, + sand – 2 mm – marked hereinafter as MPC1,
- Cement-sand mixture with proportions per 0.1 m^3: 30kg of a 42.5 cement, 20l of water, + sand – 2 mm – marked hereinafter as MPC2.

Preparation of materials for the study

All samples were prepared in accordance with the recommendations contained in the product technical datasheets. The temperature and relative humidity during sample preparation were the same (+ 22°C, 55% rH). Samples were prepared in 15x15 cm x 5 cm molds. The samples were mixed according to the manufacturer's instructions and compacted during forming. For the first 48 hours, samples were stored in a climatic chamber at 25°C and 95% rH until they were demolded. After demolding, the samples matured in laboratory conditions (average 23°C and 55% rH) until they reached the manufacturer guaranteed strength (28 days).
In order to increase the number of measurements, prepared samples were cut using a concrete electric saw with a diamond disc into smaller sections. After cutting out, the samples obtained a dimension of 5 x 5 x 5 cm.

Determination of the water absorption of the samples

To conduct the moisture test, it was necessary to determine the water absorption of the samples to evaluate the maximum amount of water that can be absorbed and then determine the maximum moisture content of the counter-floors being tested. For this purpose, previously prepared 5 x 5 x 5 cm samples were dried in a laboratory dryer to a constant weight. Drying temperature for samples JA1 and

JA2 was 40±2°C, for samples JC1, JC2, MCP1, and MCP2 was 105±2°C. Drying took place until the samples obtained a constant mass.
After obtaining a constant weight, the samples were weighed. Water absorption testing was done on the basis of the standard 6. A large container was prepared for the samples. The materials tested were placed in it and then flooded with water to ¼ of their height for a period of 1 hour. After that time, water was added to ½ of their height and allowed to stand for another 2 hours. After this time, water was added to ¾ of the height of the samples, left for 4 hours, and finally, the samples were completely flooded and left.
Samples after 24 hours obtained a constant mass. After further weighing and stating that the samples obtained the maximum degree of soaking, they were removed from the bath. After draining off the water and wiping with a damp cloth, the samples were weighed. On the basis of weighing results of dried samples and those obtained after soaking, their maximum water absorption values were determined. After establishing the water absorption of the samples, they were further stored in a climatic chamber under constant temperature conditions (25°C and 60% rH). At set intervals, decided based on other experiments conducted by the authors of the paper, individual samples were removed from the dryer and their weight (water) loss was controlled. On this basis, it was possible to determine the mass moisture of each sample at a given time. A series of samples were then removed and tested using the laboratory method, and the CM method.
After obtaining moisture characteristics for the test series, samples were removed from the climatic chamber and wrapped in stretch foil. The samples were then left for about 10 days to equalize the moisture throughout the sample volume. After this period, the samples were prepared for gravimetric and CM testing.

Moisture testing by the gravimetric method

After removing the foil, each sample was divided into two more or less equal parts. One part was immediately weighed and placed in the dryer. The second was re-foiled. The mass moisture in the test was determined according to the formula:

$$w_m = \frac{m_w - m_s}{m_s} 100\% = \frac{m_{water}}{m_s} 100\% \qquad (3.2)$$

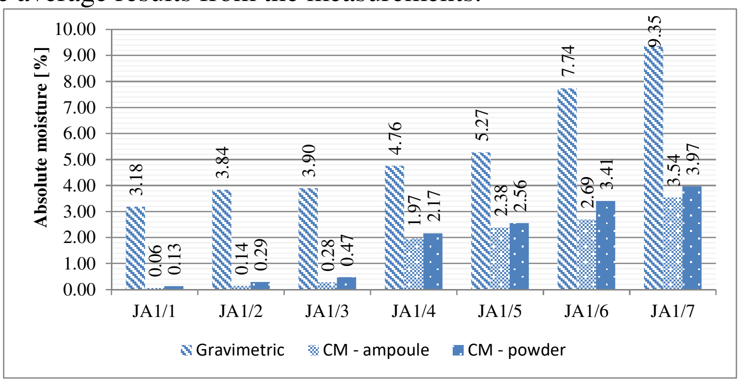
where:
w_m - moisture weight [%]
m_w - wet sample mass [kg, g]
m_s - sample mass at the time of testing [kg, g]
m_{water} - mass of water contained in the sample [kg, g]

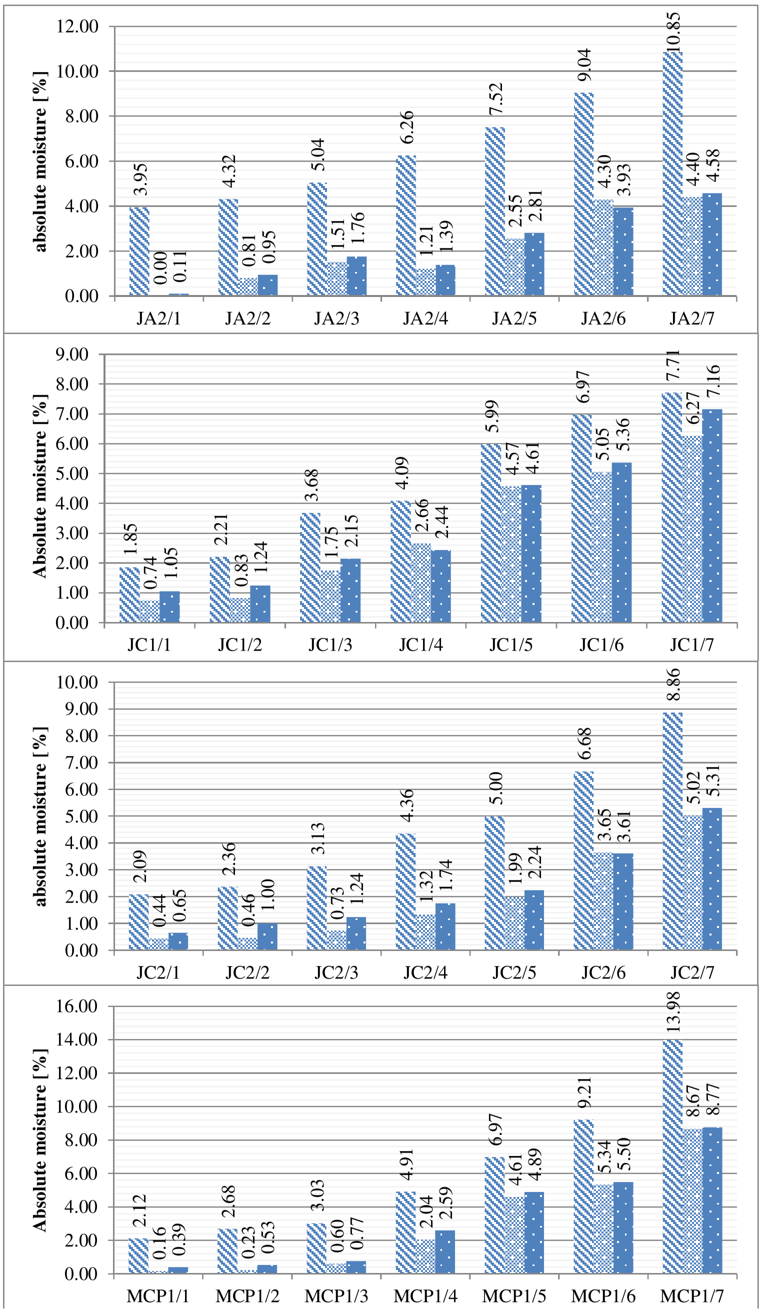
4. MOISTURE TESTING BY THE CM METHOD

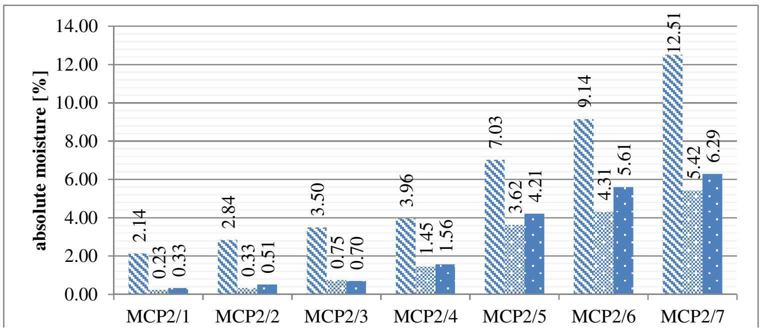
The moisture test was carried out on parts of the samples that had previously obtained the required moisture and were wrapped in foil until the test (so as not to lose the moisture level). The materials were mechanically crushed using a mortar and divided into parts for testing using two different carbide feeding methods. The first method consisted of introducing carbide in a glass ampoule and breaking it while shaking the device, the second involved powdered carbide given in the device lid. Each series was tested on 4 samples for each method. Thanks to this, apart from comparing the study with the gravimetric method, a picture of differences related to the carbide introduction method was also obtained.
The samples for testing were ground in a laboratory mortar so that the dimensions of the largest parts were a maximum of 2 mm. Part of each sample obtained in this way was weighed to 10g with an accuracy of ± 0.2g. The weighed sample was poured into the measuring chamber, and two teaspoons of carbide were poured into the lid, or in the case of moisture testing on the third part of the sample, a carbide ampoule was placed in the chamber. The cover was then slid into the chamber in such a way that the carbide did not come into contact with the particulate material. After closing the container, it was shaken several times up and down, inverted, and the shaking was repeated. This operation was repeated about every 1 minute. After 4 minutes, the manometer result could be read from a vertical position. After each reading, the container was opened, and unreacted residue was shaken out and thoroughly cleaned for the next measurement.

Experimental research results

On the basis of the experimental tests, the actual moisture and the CM moisture were determined for the samples in the series. The results presented in the charts below are average results from the measurements.




absolute moisture [%]
12.00
10.00
8.00
6.00
4.00
2.00
0.00
JA2/1 3.95 0.00 0.11
JA2/2 4.32 0.81 0.95
JA2/3 5.04 1.51 1.76
JA2/4 6.26 1.21 1.39
JA2/5 7.52 2.55 2.81
JA2/6 9.04 4.30 3.93
JA2/7 10.85 4.40 4.58
Absolute moisture [%]
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
JC1/1 1.85 0.74 1.05
JC1/2 2.21 0.83 1.24
JC1/3 3.68 1.75 2.15
JC1/4 4.09 2.66 2.44
JC1/5 5.99 4.57 4.61
JC1/6 6.97 5.05 5.36
JC1/7 7.71 6.27 7.16
absolute moisture [%]
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
JC2/1 2.09 0.44 0.65
JC2/2 2.36 0.46 1.00
JC2/3 3.13 0.73 1.24
JC2/4 4.36 1.32 1.74
JC2/5 5.00 1.99 2.24
JC2/6 6.68 3.65 3.61
JC2/7 8.86 5.02 5.31
Absolute moisture [%]
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
MCP1/1 2.12 0.16 0.39
MCP1/2 2.68 0.23 0.53
MCP1/3 3.03 0.60 0.77
MCP1/4 4.91 2.04 2.59
MCP1/5 6.97 4.61 4.89
MCP1/6 9.21 5.34 5.50
MCP1/7 13.98 8.67 8.77



Analysis of the experimental research results

The graphs obtained show the results of moisture measurements depending on the type of material and its initial moisture during testing by various methods (gravimetric and CM). Despite significant variation in results, it is possible to find certain connections and dependencies.

Based on the study of water absorption of the materials, some conclusions about their structure can be drawn. The water absorption of materials is equal to the maximum moisture determination on the charts. Based on the study, it was found that anhydrite jointless floors have higher water absorption than cement jointless floors. On the other hand, counter-floors made of a cement-sand mixture (due to their highly porous structure) show the overall highest water absorption. This information is important because the amount of water that the material can absorb is in close relation to the time it needs to be dried.

Another observation, however, is the minimum possible moisture level of the counter-floors tested. Each time, the counter-floors were dried to a constant weight; however, it turns out that the relationships here are slightly different. Due to the different structure of the counter-floors, it is not possible to evaporate all the water (some water is retained in microcapillaries and gel pores). Based on the tests, it was found that anhydrite jointless floors retain the most water and cement, the least. This may be due to the fact that, according to the standard 12, the drying temperature of gypsum and anhydrite counter-floors is lower (40°C) and does not allow the removal of all water from the microstructure. In the case of cement samples (dried at 105°C), only chemically bound water remained in the structure. More detailed analysis and comparison of the results of the study using the CM method should indicate a more certain relationship.

In all samples tested, significantly lower moisture results were obtained during the CM test. The highest average differences were achieved for the anhydrite jointless floors, the smallest for cement jointless floors. Such large differences in measurements between the gravimetric (laboratory) method and the CM method may be because the CM method is able to determine only the amount of "free"

water being the water which, enclosed in a microstructure, can react with carbide. In the case of the gravimetric method, the increased sample temperature increases the pressure in the pores and capillaries, and the water evaporates.
Analyzing the graphs presented above, it was noted that the moisture difference in the case of the anhydrite samples is more constant than proportional. The difference between the results for the lowest moisture values is similar to those between the results for higher moisture (approx. 3.3%). In the case of moisture at the limit of the water absorption of the sample, this is slightly upset; however, this is due to the large surface moisture of the material.
The situation is slightly different for the cement jointless floors and cement-sand mixes. Here, as the initial moisture of the test increases, the measurement error decreases in percentage. There is no constant moisture difference. For example, the measurement difference between methods for samples designated as MCP1 at the lowest moisture is about 92%, while the maximum water absorption of the sample is only 38%. The same is observed for JC1 (for min. 60%; for max. 19%), JC2 (for min. 79%; for max. 43%), and MCP2 (for min. 90%; for max. 57%). This means that in the case of JC and MCP counter-floors, more similar CM test results to the results of actual moisture were obtained for higher moisture levels.
In addition, no significant changes in the CM test were observed with different carbide application methods.

5. CONCLUSIONS

- Counter-floors (anhydrite and cement jointless floors, cement-sand mixtures) are materials with completely different characteristics, properties, and structure. These materials also have a different water absorption level.
- For the anhydrite jointless floors, a constant error value was observed during the CM measurement.
- In the case of the cement jointless floors and cement-sand mixtures, a percentage decrease in the measurement difference between the methods was observed along with the increase of the initial moisture of the material tested.
- The differences in moisture between the gravimetric test and the CM method are significant (sometimes even several times) and these methods cannot be used interchangeably, therefore, the results should not be treated equally. The laboratory method is a direct method and determines the actual moisture content of a material. To determine the actual moisture in a counter-floor using the CM method, appropriate correction formulae should be determined. Depending on the material tested, these equations will be different.
- No significant differences were found during the CM test for different carbide application methods.

REFERENCES

1. Adamowski, Jand Matkowski, Z 1999. Ocena skuteczności osuszania ścian murowanych. *Materiały Budowlane* **4**, 131-137.
2. Gąsiorowska, D 2005. *Wykonywanie podłóg 311[04].Z3.03. Poradnik dla ucznia*. Radom: Instytut Technologii Eksploatacji - Państwowy Instytut badawczy.
3. Kupfer, K 1997. Materialfeuchtemessung. Grundlagen, Meßverfahren, Applikationen, Normen 513 (Kontakt & Studium). Renningen-Malmsheim: Expert-Verlag.
4. Nilsson, L 1980. *Hygroscopic moisture in concrete - drying, measurements & related material properties*. Lund: Division of Building Materials, LTH, Lund University.
5. Trochonowicz, M and Szostak, B and Lisiecki, D 2016. Analiza porównawcza badań wilgotnościowych metodą chemiczną w stosunku do badań grawimetrycznych wybranych materiałów budowlanych. *Budownictwo i Architektura* **15(4)**, 163-171.
6. BS EN 13755:2008. Natural stone test methods. Determination of water absorption at atmospheric pressure.
7. Czarnecki, L 2007. Badania i rozwój posadzek przemysłowych. Materiały Budowlane 5, 6–8.
8. Rudek, L 2017. Płynne anhydrytowe podkłady podłogowe. Construction Materials 1 (9), 9–10.
9. Świątek-Żołyńska, S 2017. Beton posadzkowy - wymagania i odpowiedzialność za jakość zgodnie z PN-EN 206. *Construction Materials* **1(9)**, 5–8.
10. Turski, D 2017. Parkiet, deska warstwowa czy LVT. Współczesne rozwiązania, różne wymagania. *Construction Materials* **1(9)**, 50–52.
11. Witkowski, M 2017. Wymagania estetyczne i użytkowe stawiane posadzkom. *Construction Materials* **1(9)**, 46–48.
12. ISO 12570. Hygrothermal performance of building materials and products — Determination of moisture content by drying at elevated temperature.

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