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Wood moisture of rural timber constructions

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Abstract: The aim of this paper is to present the methodology of measurement of moisture content of wood and show some results of this measurement in application on constructions of agricultural buildings. Wood moisture can affect the durability of buildings. Measurements are in two different animal houses, which varied in design and implementation of the construction material (steel-wood and steel with wooden rafters). Both these buildings are relatively new (built in 2001 and 2009). There was measured also an older shed attached to the barn, which has a storage and protective function. All these buildings are from spruce wood. The measurement was based on the use of resistive sensor and capacitive sensor. Also determined was the temperature and humidity of the air.
From the results of measurements of tested buildings it is obvious that the moisture of the wood is in direct proportion with the relative humidity of the air. There are different results measured by capacitive and resistive sensors. The suitability of the sensors for determination of wood moisture was verified by gravimetric method, that is direct method and the results are very accurate. In the case of coniferous wood (especially spruce wood), there can be used with sufficient accuracy a capacitive sensor, which was used in all examined buildings.

Key word: animal houses, wood, measurement, moisture content.

INTRODUCTION

The aim of this paper is to present the methodology of measurement of moisture content of wood and show some results of this measurement in application on constructions of agricultural buildings. Timber has always been widely used as a building material in rural constructions in many countries of the world. The reason is that wood has many advantages. Timber is easily available, many farmers can use wood from their own forest, it is not too complicated for processing, it is strong and light and it can be sufficiently durable. But the durability of buildings can be affected by wood moisture.

As a timber are used coniferous and deciduous trees. Spruce (*Picea abies*) is the most important tree used as timber in the Czech Republic. Also the wood of spruce silver fir (*Albies alba*), scots pine (*Pinus silvestris*), larch (*Larix decidua*), oak (*Quercus robur*), beech (*Fagus silvatica*), black poplar (*Populus nigra*), alder (*Aldus glutinosa*) and exotic wood (Hujnak, 1986; Vavrcik & Gryc, 2008). Besides the solid wood there is also a wide range of wood-based materials, e.g. plywood boards, agglomerated boards, veneers, chipboards, etc. The main aspects of material selection are not only mechanical and physical properties, but also the price, availability and aesthetic aspects (Kral, 2008; Kral et al., 2008; Stefko et al., 2009).

Structural protection of wooden buildings means primarily the following measures: selection of appropriate types of wood and wooden materials (using wood with a relatively high strength), ensuring the quality of timber, protecting wood against increased moisture, and respecting the fire safety principles (Stefko et al., 2009).

Moisture has a great importance in the processing and use of wood. Wood as a hygroscopic material reacts to the moisture conditions in the environment, which is reflected in the shape changing (swelling and shrinking), if the moisture content is about 20% or more in combination with suitable temperature (15 °C or more), there are suitable conditions for insects and fungi invading and decaying the wood (Holan, 2008). This paper also includes the study of changes of moisture content in livestock buildings in response to changes in relative humidity of the air.

There were measurements taken in two different animal houses, which varied in design and implementation of the construction material (steel-wood and steel with wooden rafters). Both these buildings are relatively new (built in 2001 and 2009). There was also measured an older shed attached to the barn, with a storage and protective function. All buildings are from spruce wood. The measurement was based on the use of a resistive sensor and capacitive sensor. The temperature and humidity of the air was also determined.

Besides the above-described objects, there was measured the moisture of spruce wood by the direct (gravimetric) method because of differences between results of indirect (capacitive and resistive sensor) method. From the results of the measurements it is obvious that the moisture in the wood is in direct proportion with the relative humidity of the air.

MATERIALS AND METHODS

The basic assumption of this research is to perform measurements of wood moisture in existing animal houses and verify the suitability of two types of sensors for these measurements. The measurement was based on the use of resistive sensor and capacitive sensor. It also determined the temperature and humidity of the air. The suitability of the sensors for determination of wood moisture was verified by gravimetric method, that is direct method and the results are very accurate. The disadvantage of this method of determining the actual moisture content is that it partially disrupts the building structure, and therefore this method cannot be applied to real existing construction.

The sensors were connected to the data logger ALMEMO 2690–8. Used for the indirect measurement of wood moisture capacitive sensor FH A696–MF with operative range of wood moisture from 0 to 50% with accuracy 0.1% and resistive sensor FH A636–MF with operative range of wood moisture from 7 to 30% with accuracy 0.1%. The temperature and humidity of the surrounding air were measured by sensor FH A646–2 including temperature sensor NTC type N with operative range from –30 to +100 °C with accuracy ± 0.1 K, and air humidity by capacitive sensor with operative range from 5 to 98% with accuracy ± 2%.

The suitability of the sensors for determination of wood moisture was verified by gravimetric method, that is direct method and the results are very accurate. There was used for the drying of the sample of spruce wood the electric oven Memmert UNB with automatic control of temperature and natural flow of air inside the chamber. Drying of the wood sample was with a temperature of 105 °C. Sample was weighed on the laboratory balance KERN–440–35N. Maximum load weight is 400 g with resolution 0.01 g.

The disadvantage of this gravimetric method of determining the actual moisture content is that it partially disrupts the building structure; this method has not been applied to the real existing constructions. Therefore, used were non-destructive methods of indirect measurement of resistive and capacitive sensor in the real studied construction. The results of measurement were verified by statistical hypothesis tests (t-test and Wilcoxon-test), (Svatosova & Kaba, 2005).

The following animal houses were measured.

Cowshed A

This cowshed was completed in 2009 as a new building, used for loose housing of 246 dairy cows in stalls with rubber mats. Construction is combined steel-wood. Steel support columns and internal supports are in combination with timber roof beams of glued laminated wood. Wood is used also for one gable, the other is from bricks. The roof is saddle shaped. Span is 32.1 m; the length of cowshed is 60.6 m with construction module 6 m.

Cowshed B

This stable was built in 2001 as a new building, used for loose housing of 567 dairy cows without straw bedding. Cowshed construction is made from steel with wooden rafters. There are obvious problems with fungi on the rafters. Stable span is 32 m; the length of cowshed is 138 m with construction module 4.8 m.

Barn C

This building is an old wooden shelter, which is a brick outbuilding, located to the barn in a private country house. The age of the shelter is about 75 years.

RESULTS AND DISCUSSION

The main objective of this article is to show the results of measurement of moisture content of wood, which is used for construction of animal houses and compare different methods and sensors for this measurement.

Determination of wood moisture content by indirect methods (capacitive and resistive sensors)

There were selected three different parts of timber construction in each building in which has been measured the moisture content of wood (10 measurements using capacitive sensor and 10 measurements using resistive sensor) on different days, at different relative humidity and air temperatures. The average value of each sensor measurement and also the air humidity and temperature was calculated from the results of measurement according to the following equation:

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}, \tag{1}$$

where x_i – value of the i-th measurement; n – number of measurement.

Cowshed A

Measured in three parts of the timber construction: glued truss rafters, board of side roller shutter and column of gable. Measurements were at temperatures from 5 to 18 °C. The comparison of results of the capacitive and resistive sensors for all three measurement locations are shown in Fig. 1.

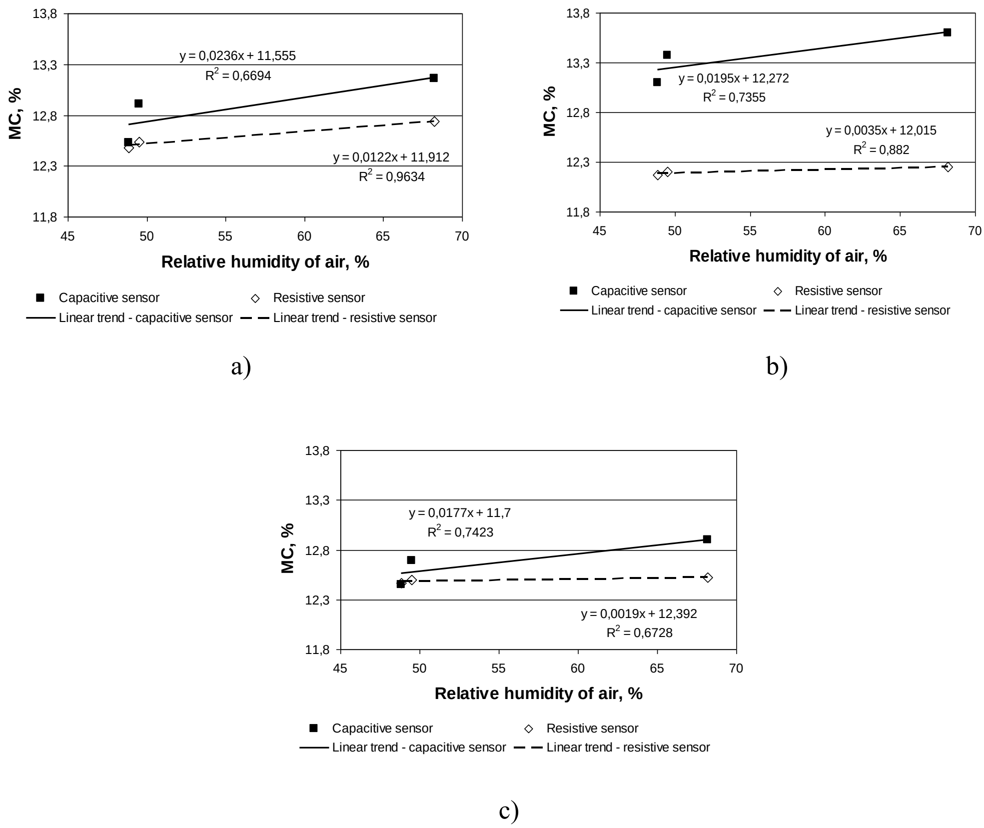

Figure 1. Moisture content of wood in cowshed A, measured in three different parts. a) glued truss rafters, b) board of side roller shutter, c) column of gable.

The results indicate the increasing moisture content with increased air humidity. In no case did the moisture content exceed the critical limit of 20%. The data obtained from capacitive and resistive sensor show a similar trend, but the values of capacitive sensor are higher (up to 1.4%) than obtained by resistive sensor.

Cowshed B

Measurement took place in cowshed B because of the obvious attack of wooden rafters by decaying fungi (Fig. 2). Measured in three parts of timber construction: two rafters and board of side roller shutter. With the same type of wood material (massive wood), measurement results from this cowshed shown in Fig. 3 are the average value from all measured locations. Measurements were at temperatures from 2.5 to 21.2 °C.

Figure 2. Wooden beams exposed to fungi.

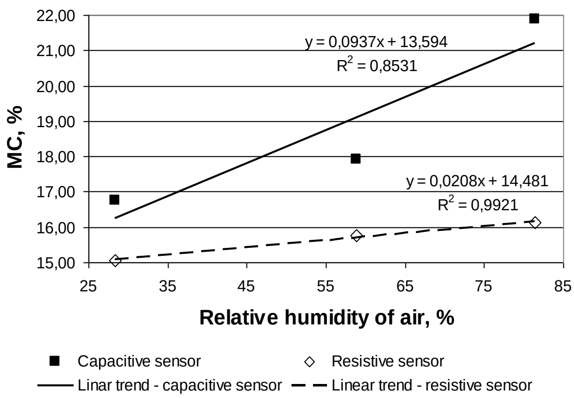

Figure 3. Moisture content of wood in cowshed B.

There is also in the measurement of cowshed B increasing moisture content of wood related to increased air humidity. However, in the case of this building is a greater difference between the data obtained by capacitive and resistive sensor. While the results from resistive sensor are in the range of 15–16.2%, the results from the capacitive sensor at high air humidity achieved the moisture content over 20%, especially in the case of roof rafters. These conditions facilitate the development of wood-destroying fungi.

Barn C

There was also measured in three parts of this old timber construction: roof beam, supporting pole (measured in level 30 cm above the floor) and wall plate. As all parts are the same type of wood material (massive wood), measurement results from this barn shown in Fig. 4 is the average value from all measured locations. Measurements were at temperatures from 7.8 to 20 °C.

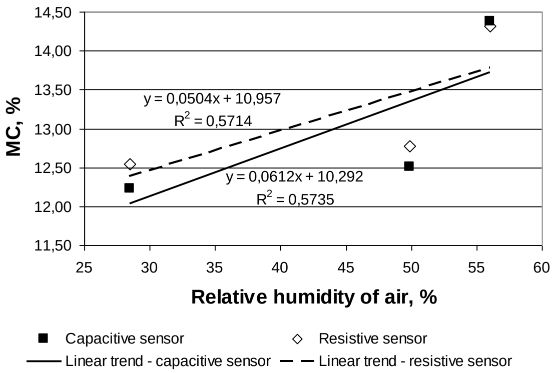

Figure 4. Moisture content of wood in barn C.

Even in the case of relatively old timber construction the results of measurement confirmed that wood moisture content reacts to ambient air humidity. This measurement also showed that in the case of using dry and well-prepared timber, the buildings have sufficient durability. The values obtained by capacitive and resistive sensors are in the case of these measurements very similar.

Determination of wood moisture content by direct method (ovendrying)

According (Koschke, & Huttl, 2002) moisture content is usually determined on wet basis (WB) and dry basis (DB):

$$MC_{WB} = \frac{M_I - M_F}{M_I} \cdot 100, \qquad (2)$$

$$MC_{DB} = \frac{M_I - M_F}{M_F} \cdot 100, \qquad (3)$$

where MC_{WB} – moisture content determined on wet basis, $\%_{WB}$; MC_{DB} – moisture content determined on dry basis, $\%_{DB}$; M_I – initial weight, kg; M_F – final weight, kg.

For direct method, there were used two samples of spruce wood. The initial weight of samples was 0.190 kg and 0.049 kg. Both samples could not be taken from tested buildings, so the samples were taken from naturally dried spruce wood. Drying of the samples was carried out once for 31.25 hours at 105 °C. Every 45 minutes the samples were weighed again. The bigger sample was measured also by capacitive and resistive sensor (smaller sample was too small to be measured by capacitive and resistive sensor). Capacitive sensor provides data from 2% of moisture content of wood and resistive sensor provides data only from 9% of MC. Results for MC_{WB} are shown in Fig. 5 and results for MC_{DB} are shown in Fig. 6. Both figures contain curves of moisture content of spruce wood detected by capacitive and resistive sensors.

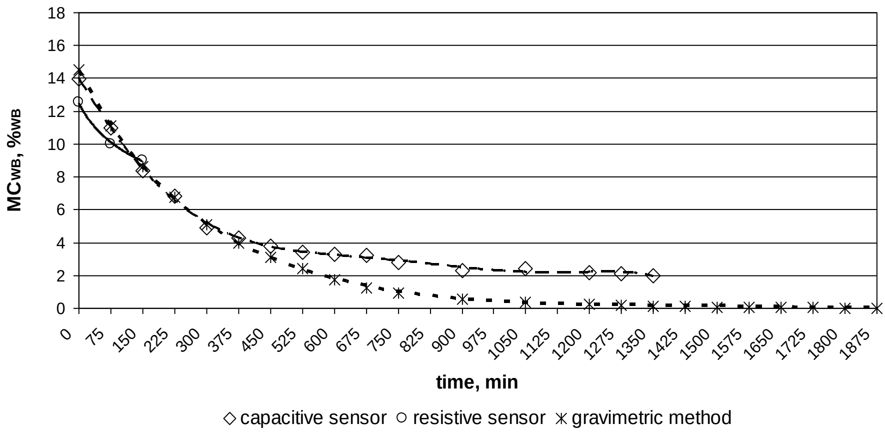

Figure 5. Moisture content (wet basis) of spruce wood.

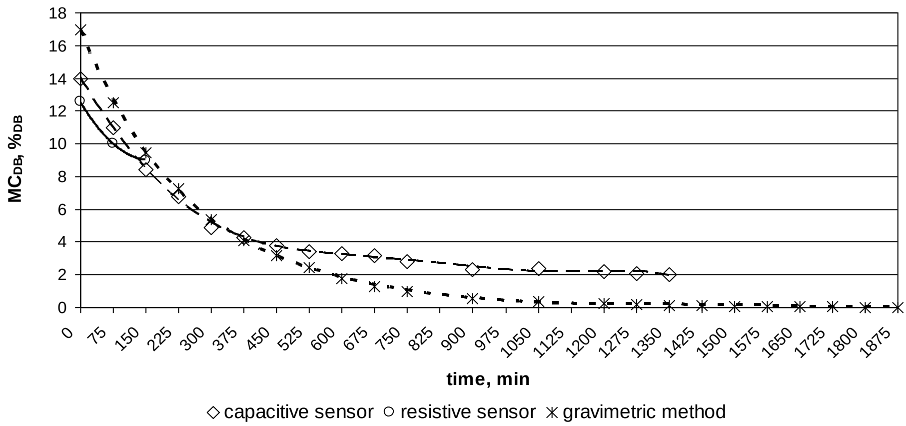

Figure 6. Moisture content (dry basis) of spruce wood.

Previous figures show that in the case of MC_{WB}, the results obtained by capacitive sensor are identical with the results determined by gravimetric method if the value of moisture content is over 4%. It was confirmed by statistical analyses based on the *Wilcoxon*-test. The difference between the measured values by direct gravimetric method and capacitive sensor are not statistically significant at level 0.05 ($W = 13 > W_{critical,\ 0.05} = 2$). The results obtained by resistive sensor were not tested by *Wilcoxon*-test, as the number of measurement was smaller. These data were evaluated by *t*-test and the difference between these measured values and MC_{DB} was not statistically significant at level 0.05 ($t = 1.13 < t_{critical,\ 0.05} = 4.303$).

In case of MC_{DB}, both the sensors show lower results than gravimetric method. However the differences between the measured values by direct gravimetric method and capacitive sensor are according to *Wilcoxon*-test not statistically significant at level 0.05 ($W = 34 > W_{critical,\ 0.05} = 30$). The results obtained by resistive sensor were not tested by *Wilcoxon*-test. These data were also evaluated by *t*-test and the difference between these measured values and MC_{DB} was not statistically significant at level 0.05 ($t = 1.08 < t_{critical,\ 0.05} = 4.303$).

It can be said that according to the statistical analyses both sensors can be used for this type of wood moisture measurement, nevertheless according to the graphs the capacity sensor gives more accurate results than resistive sensor.

CONCLUSIONS

The results of measurement show that the timber structures can be influenced by the surrounding and in-door conditions. The moisture of the wood is in direct proportion with the relative humidity of air.

Relative humidity of air in cowshed A and barn C during the measurement does not exceed 65% and the moisture content of wood in these two buildings were below the critical limit of 20%, also there was no visible damage to wooden elements. In cowshed B relative humidity of air exceeded 80% during measurement and the measured moisture content of wood was over 20%. The wooden elements in this cowshed already showed the first signs of damages by fungi. This could cause problems in the future.

There are different results measured by capacitive and resistive sensor, especially in the case of cowshed B. The capacitive sensor showed moisture content over 20% while the resistive sensor indicated the moisture content only around 16%. To verify the accuracy of the sensors, there was used the gravimetric method. Based on the results of the gravimetric method, it could be said that in the case of MC_{WB} capacitive sensor gives very accurate results, while the resistive sensor data indicates slightly lower values. In the case of MC_{DB} both sensors indicate lower values than the real values. It was confirmed by statistical analyses that there is no significant difference between both non-destructive methods and direct gravimetric measurement.

In the case of spruce wood (used in all examined buildings), there can be used with sufficient accuracy a capacitive sensor. Generally, the advantage of these indirect methods is that they can be used for control of moisture content in existing buildings.

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