WOOD RESEARCH
64 (3): 2019
529-536

MOISTURE CONTENT ANALYSIS OF WOODEN BRIDGES

Roman Fojtík
Vsb-Technical University of Ostrava, Faculty of Civil Engineering Department of Building Structures
Ostrava, Czech Republic

(Received December 2018)

ABSTRACT

The article deals with assessing the impact of moisture content conditions in wood mass of the wood bridges constructions on their lifespan in Central Europe. Wood moisture content as one of main factors influencing the wooden elements mechanical properties was studied on seventeen wooden bridge constructions. The dependence of temperature and relative humidity on material moisture content was observed in summer season and also in winter season. The lifespan of historical and modern wood structures was discussed as well.

KEYWORDS: Wood, diagnostics, bridges, moisture content.

INTRODUCTION

Wood as a building material proved its worth both from the standpoint of mechanical properties and of building structures lifespan as well. Plenty of wooden bridges and footbridges that have withstood for centuries can be found in the area of Central Europe. These bridge constructions include e.g. historic construction of bridge structure in Černvír municipality, Czech Republic, built in 1719. This construction has withstood for 300 years with original supporting structure, without modern chemical fungicides. There are dozens of such bridge constructions in Central Europe (Bak et al. 2012, Fojtík et al. 2017).

Fig. 1: Bridge Černvír in the ČR (Bak et al. 2012).

One factor which may influence the lifespan of these historic constructions without chemical protection is moisture content conditions of wood mass. The biggest threats of these constructions from the standpoint of moisture content conditions are biological pests. This fact can be observed on some modern structures the lifespan of which has made just about 3% of those historic ones. Their relatively short destruction was caused by biological factors only, the Family Gloeophyllaceae.

The question is whether moisture content parameters of historic and modern constructions differ greatly, which might show the possible cause of short lifespan of some modern structures.

Wooden bridge constructions are built all over the world and it is obvious from available sources (Fojtík and Dedkova 2016, Fojtík et al. 2017) that wooden bridge constructions can withstand for hundreds of years. Wood is local raw material that more or less varies according to particular areas.

The quality of wood can be observed from many points of views; some of these are mechanical properties, durability, resistance to biological pests, and others that are described in details in specialized literature (Borges et al. 2017, Reinprecht 2016, Reinprecht and Vidholdova 2017, Rumlova and Fojtík 2014).

MATERIAL AND METHODS

All monitored modern bridge structures in the area of Central Europe are made of spruce wood (*Picea abies*). The probable argument of this monopoly is the price and availability of spruce timber in particular locality. Wood moisture content is one of chief factors of wooden elements mechanical properties. That is why 17 wooden bridge constructions, both modern and historic were monitored to record surface and internal moisture content in dependence on the temperature. Especially, different humid conditions of massive supporting elements were observed (Fojtík and Dědková 2016, Lokaj et al. 2016, Reinprecht et al. 2001, Shirouzu et al. 2016, Vavrušová et al. 2016).

RESULTS AND DISCUSSION

Wood as an organic, non-homogenous, anisotropic and hygroscopic material is influenced by external environment. Wood moisture content, dependent on external environment, represents in long-term horizon noticeable influence. The wood moisture content influences not just mechanical properties but also lifetime of the structure. Risk moisture content limit is related to the occurrence of biological pests. It is a primary risk from the standpoint of longevity of bridge wooden structures that can cause serious defects in a relatively short term.

Dependence of wood moisture content on external environment was monitored on 14 modern bridge constructions (of glued lamellate spruce wood), below the age of 10 years, and three historic structures. Following charts show readings of surface moisture content measured on the surface of the structure and internal moisture content monitored inside the profile.

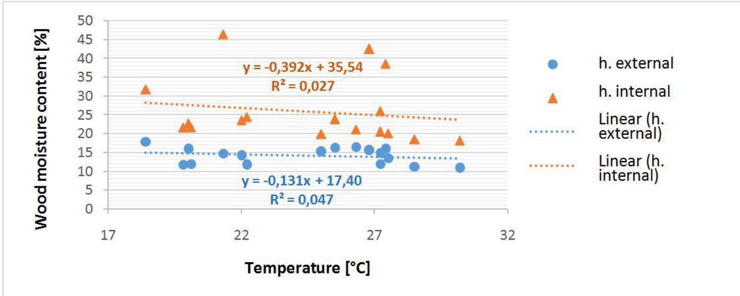

Fig. 2: Dependence wooden material moisture content as a function of temperature in summer season.

Fig. 2 indicates external and internal moisture content of monitored structures at different temperatures in summer season which brings higher absolute air moisture content. If the points are approximated with linear functions, we can see the decrease in moisture content while the temperature increases. The graph shows that both surface and internal wood mass can dry slightly. In the case of moisture content of internal material above 30% incipient defects were detected on a structure.

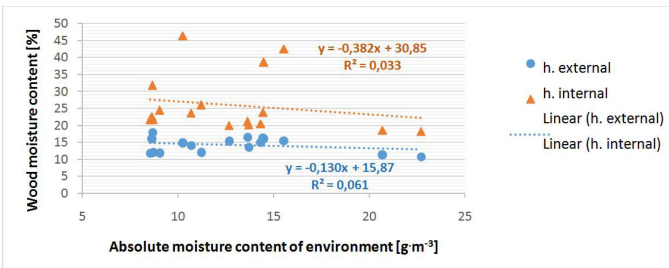

Fig. 3: Dependence of wooden material moisture content as a function of absolute moisture content of environment in summer season.

Fig. 3 describes dependence of wood mass moisture content (surface, internal) as a function of absolute moisture content of environment. It is obvious from the graph that the wood mass dries even when the absolute moisture of environment increases. On the basis of the facts we can say that temperature is the most significant driver influencing the wood moisture content.

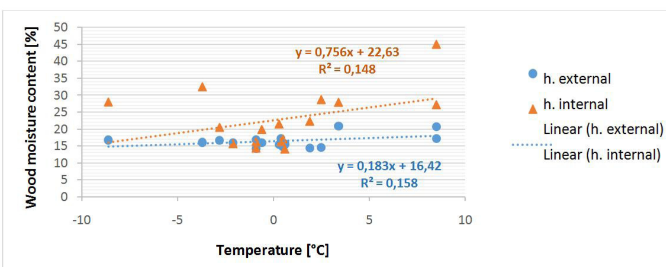

Fig. 4: Dependence of wood moisture content as a function of temperature in winter season.

Fig. 4 shows dependence of wood moisture content from external temperature in winter. It is obvious that the decrease in temperature is concurrent with the decrease in moisture content. It is an opposite effect to the one in summer term when the temperature increases while the wood moisture content decreases.

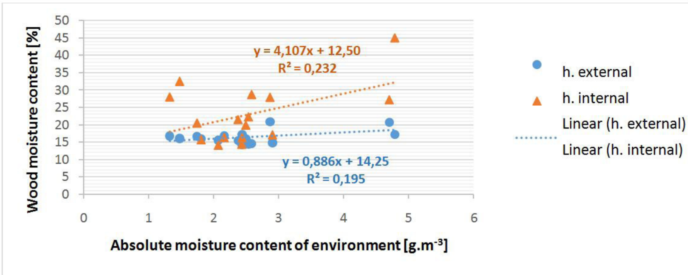

Fig. 5: Dependence of wooden material moisture content as a function of absolute moisture content of environment in winter season.

Fig. 5 shows values of wood moisture content at relevant absolute moisture content of the environment. The graph indicates that decrease in absolute moisture content of the environment is concurrent with decrease in humidity of wood where the internal material moisture content decreases steeply. It is possible to say that wood drying is influenced not only by dropping temperature but also by the absolute moisture content of the environment.

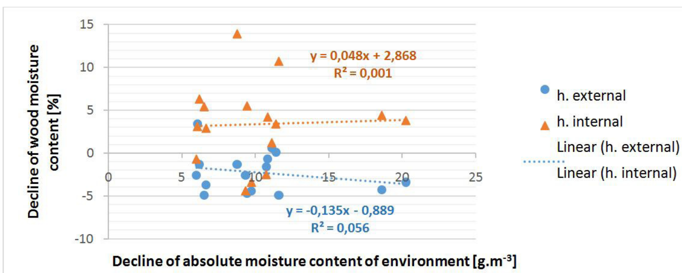

Fig. 6: Dependence of decline of wood moisture content as a function of decline of absolute moisture of the environment.

Important Fig. 6 describes dependence of decline of wood moisture content (the difference between summer and winter moisture content) on decline of absolute moisture content of the environment (the difference between summer and winter decline). The linear curve corresponding to external (surface) moisture content indicates obvious decline in wood humidity at absolute values with decline of absolute moisture of environment.

Even a difference between external and internal moisture content in different year seasons can be specified on the basis of data mentioned above. There is an average distinction of 8.88% in summer season, while the distinction in winter season makes 5% only. This condition is caused by rise in surface moisture content and drop in internal moisture content in the winter season.

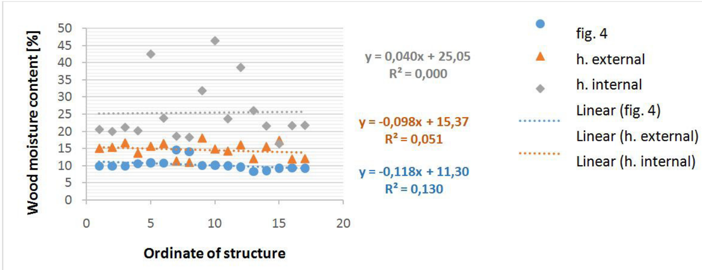

Fig. 7: Comparison of values from Fig.4 with actual measured data in summer season.

Fig. 8 shows that taken readings from Fig. 4 are 1.45 times lower than actual measured data given for wood moisture content in the summer season. In the case of internal moisture content, the proportion is even 2.54 times higher.

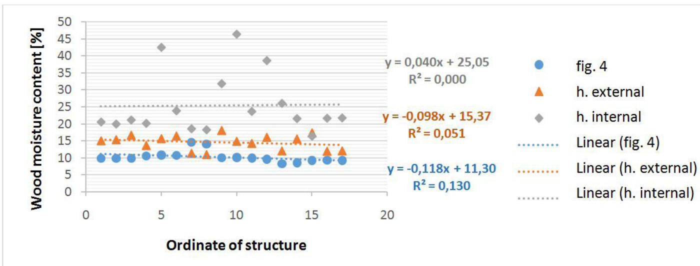

Fig. 8: Comparison of values from Fig.4 with actual measured data in winter season.

Fig. 8 describes the same parameters as Fig. 7 but in the winter season. Obtained linear curves correspond to the previous graph. The surface moisture content of wood is 1.45 times higher than moisture content taken from the Fig. 3. The proportion in internal wood moisture content y is 2.54 multiple of moisture content values obtained from Fig. 3.

It is obvious from Fig. 7 and 8 that theoretical values of wood moisture content taken from Fig. 3 differ significantly from data obtained experimentally in terrain. In spite of a short time of monitoring of actual structures moisture content, it is possible to state that application of graph from Fig. 3 is not appropriate for exterior structures.

Almost identical surface moisture content can be monitored when comparing average moisture content at modern and historic bridge constructions in summer and winter season – as shown in the Tab. 1. This can be a comparative parameter for internal humidity which is the key one for the probable origin of biological damage.

Tab. 1: Average moisture content at monitored structures in summer season.

Age of structure	Average external moisture content (%)	Average internal moisture content (%)
Historic bridges	14.67	22.15
Modern bridges	14.10	22.46

Average internal moisture content in summer season differs minimally and this indicates that behaviour, from the standpoint of external and internal moisture content, is the same in both historic and modern bridges.

Tab. 2: Average moisture content at monitored structures in winter season.

Age of structure	Average external moisture content (%)	Average internal moisture content (%)
Historic bridges	17.10	16.30
Modern bridges	16.01	23.61

The difference of internal moisture content is much more significant than external moisture content between summer and winter season. While both internal and external moisture content has increased by units of percent on average in modern bridge structures, the internal moisture content in historic structures has dropped considerably. Additionally, the comparisons of obtained results to nomograms of dependence of moisture content of sawn timber as function of a temperature and relative air moisture content were carried out. It has been found out that the obtained data were not the same in nomograms.

The reason is specialization of nomograms in the interior, not exterior. Measurements show the incompatibility of wood moisture content in exterior with available nomograms (Martensson et al. 1992, Fojtík et al. 2017).

The history has shown that wooden bridge constructions can withstand for hundreds of years. Lifespan of some modern wooden bridge constructions achieves not even 10% of those historic ones. Modern constructions differ from the historic ones in many things, from the structure via details to the structure of wooden mass. Moisture content is one of important factors influencing especially mechanical properties; it can also have an important impact on the durability of these structures. The basic risk is associated principally with biological pests, the most threatening of whom are wood-decaying fungi of the Family: Gloephyllum (Bak et al. 2012, Fojtík and Dědková 2016, Vašková et al. 2016).

CONCLUSIONS

In this study, the comparisons of wood moisture content data of historical and modern bridges in summer and winter season have been carried out. The measurements were made in the area of Central Europe in 2018. The subject of monitoring was humidity conditions at 17 structures in summer and winter season. On the basis of obtained data it is possible to say that moisture content conditions in the cross-section change both in summer and winter season; the wood moisture content is principally dependent on the temperature and absolute moisture of the environment.

Different values between historic and modern constructions are significant especially in winter term when considerable drying inside the cross section occurs due to the low relative moisture content of environment. It is probably caused by degradation of wood in time due to which wood in historic concstructions may lose moisture more noticeably than wood in modern structures.

On the basis of performed mesaurement it is possible to say that if the project of the structure is designed properly and dried sawn timber is used, the wooden mass reports parameters which eliminate the risk of possible attack of harmful wood-decaying fungi of the Family Gloephyllum.

This measurement which included historic constructions indicates that the influence of humidity on lifespan from the standpoint of the threat of wood-decaying fungi is beneficial and these constructions can withstand hundreds of years as well as their historic precursors.

ACKNOWLEDGEMENT

This research was realized with the financial support of Conceptual Development of Science, Research and Innovations IP IP221021.

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Roman Fojtík
Vsb-Technical University of Ostrava, Faculty of Civil Engineeringdepartment
of Building Structures
Ostrava, Czech Republic
Ludvika Podeste 1875
708 33 Ostrava
Czech Republic
Corresponding author: roman.fojtik@vsb.cz