2nd International Conference on Moisture in Buildings (ICMB23), online, 3-4 July 2023

Hygrothermal limit curves and transient decay prediction for natural fibre insulation

Eri Tanaka[a], Regina Schwerd[a], Notburga Pfabigan[b], Johannes Tieben[b], Julia Bachinger[b], Daniel Zirkelbach[a]

a Fraunhofer Institute for Building Physics IBP, Holzkirchen, Germany
b Holzforschung Austria, Vienna, Austria

Abstract

In recent years, insulating materials made from renewable natural materials have gained in importance – mainly due to advantages in sustainability and carbon footprint. However, the moisture content limits specified in standards and guidelines for such materials are mostly quite low, which considerably restricts their range of application. In order to enable reliable and broader use in the various areas of the building envelope, robust limits are required that relate not only to the combination of temperature and humidity but also to the duration of their exposure. After all, microbial growth in the exterior climate is possible in most regions, at least temporarily. Therefore, a transient assessment can best evaluate how a construction must be designed to safely avoid damage. In this contribution both new limit curves and a transient decay prediction model, based on durability tests of natural fibre materials in the laboratory are proposed. First evaluations by field tests have already been performed.

Peer-review under the responsibility of the organizing committee of the ICMB23.

Keywords: durability of natural fibre insulation, hygrothermal simulation, transient decay prediction, limit curves

1. Background and aim

Insulation materials made from renewable natural materials are becoming increasingly important and popular. They improve the carbon footprint and are considered sustainable and good for indoor climate comfort. However, these materials are particularly sensitive to moisture and fungi attack. While at higher temperatures mainly mould growth prevails, decay fungi become more important at lower temperatures [1]. However, the detailed growth conditions are often not well known. Therefore, usually very low moisture limits for the design are specified in codes and standards. Based on previous research and new lab tests, limit curves are determined and a transient decay prediction model developed, which considers the crucial influencing factors like sensitivity of the material, relative humidity, temperature and the duration of their simultaneous impact.

2. Measurements in the laboratory

In addition to previous investigations with wood fibre insulations intended for use as interior insulation [2], further wood and cellulose fibre insulation materials were inoculated with three decay fungi and exposed to different climate conditions just at the limit as well as clearly in the range considered favorable for wood rot. Therefore, a relative humidity of 97% was combined with temperatures of 10 °C, 15 °C, 25 °C and 30 °C. At the lower temperatures of 10 °C and 15 °C additional tests at 100% RH were performed. The test durations were about 8 months at the higher temperatures of 25 and 30 °C and 12 months at the lower 10 and 15 °C. The specimens were observed visually concerning mycelium growth and at certain times, specimens were taken to measure their mass loss. As a reference material, also pine sapwood was exposed.

Over the investigated period, only little or no mass losses occurred at 97% RH, even not in the high temperature range, while clear mass losses up to more than 20% for some products were observed at 100% RH and 10 °C or 15 °C. Apart from one wood fibre material, manufactured in a wet production process, the other wood and cellulose fibre materials showed a higher resistivity against decay fungi than the pine sapwood. However, also the mass losses of the pine sapwood reference samples remained clearly lower than the ones in previous investigations like [3,4,5]. This may be because inoculation was largely performed without transfer of additional nutrients to represent the real situation in constructions. Also the fungal mass in relation to the specimen size was chosen significantly smaller compared to previous investigations. That means that the results confirm the limit criteria for sapwood from [6] and [3,4] and prove like [2] that some natural fibre insulation

materials can be as or even more resistant against decay fungi attack as sapwood. However, it was also found that other natural fibre insulation materials are more sensitive and therefore require individual consideration of the materials or appropriate classification.

3. Proposal of limit curves and transient prediction model

Based on the findings in [6] and [2] as well as on the new results, hygrothermal limit curves are proposed for wood and natural fibre insulation materials with two different resistivity levels. For wood and the more resistant fibre insulations, the limit curve according to [6] could be confirmed. The new results show that the previous curve is even still on the safe side when the results of 12 months exposure time at 10 and 15 °C in combination with 97% RH without any mass losses are considered. Furthermore, the first draft of a decay prediction model [6,7], presented in [6], was further developed. Therefore, both an initiation phase based on [2] and a mass loss prediction based on the lab test results was introduced. Considering the mass loss differences between the more sensitive wood fibre board (wet production process) and the pine sapwood samples, a correspondingly lower limit curve for this material at 100% RH could be derived. Also this limit curve remains on the safe side: while the wet fibre board showed in the lab a lower decay resistance than sapwood at 100% RH but a higher one than sapwood at 97% RH, the limit curve suggests a lower resistance at all RH levels.

4. First validation based on lab and field tests

Applying the model on the laboratory tests leads in all cases to an earlier start of degradation and a higher mass loss prediction than measured in the laboratory. In the same project [8] also field tests of wall constructions with cavity insulation and EIFS with natural fibre materials were performed and the hygrothermal conditions at the critical positions of the insulation layers were recorded. The decay risk at the measured conditions was evaluated by the help of the transient prediction model and compared to the condition of the fibre insulations after the test period of 13 months. The model was also on the safe side in this comparison.

5. Conclusions and outlook

Based on laboratory tests on the resistivity of natural fibre insulation materials against decay fungi, hygrothermal limit curves are proposed, which indicate, depending on the sensitivity of the material, the critical combinations of temperature and relative humidity required for wood decay. Furthermore, the transient model for decay prediction, established in [6] has been further validated for solid wood and extended, so that it can be used also for natural fibre insulation materials. The new limits and decay prediction allow higher RH and temperature conditions than suggested by previous investigations like [3,4]. This could be explained by less favorable but more realistic start conditions for the decay fungi in the recent lab tests. However, even if the first validations by lab and field tests are promising, further evaluation by both damage and well performing constructions from practice are required. Likewise, a refinement and extension of the resistance classes appears to be useful in order to adequately represent both more sensitive and significantly more resistant materials.

References

[1] Kehl, D. & Plagge, R. et al. (2012). Wann geht Holz kaputt? Nachweistechnische Beurteilung von Holz zerstörenden Pilzen. Hanseatische Sanierungstage in Heringsdorf/Usedom. p 61-73. Berlin. Beuth Verlag.
[2] Zirkelbach, D. & Tanaka, E. (2021). Evaluation of decay resistance of wood fibre insulation based on hygrothermal simulation and comparative laboratory tests. (London: Proceedings 1st International Conference on Moisture in Buildings ICMB21).
[3] Viitanen, H. (1996). Factors affecting the development of mould and brown rot decay in wooden material and wooden structures. Uppsala.
[4] Viitanen, H. & Toratti T et al. (2010). Towards modelling of decay risk of wooden materials. European Journal of Wood and Wood Products 68 3. p 303–313.
[5] Brischke, C. 2007. Untersuchungen abbaubestimmender Faktoren zur Vorhersage der Gebrauchsdauer feuchtebeanspruchter Holzbauteile. Hamburg.
[6] IBK, IBP & BTU. 2016. Energetisches Bewertungsverfahren für Bestandsgebäude mit Holzbalkendecken. PTJ-Project Nr. 0329663N/P/O.
[7] Sedlbauer, K. (2001). Prediction of mould fungus formation on the surface of and inside building components. Stuttgart. Fraunhofer IRB.
[8] Ongoing Research Project AIF CORNET ThermNat. 2022. Building components with sustainable materials: focus (hygro-)thermal conditions. IGF-Vorhaben 271EN.