Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 132 (2017) 207–212

Energy Procedia

www.elsevier.com/locate/procedia

11th Nordic Symposium on Building Physics, NSB2017, 11-14 June 2017, Trondheim, Norway

Assessment of durability of environmentally friendly wood-based panels

Urve Kallavus*, Hele Järv, Targo Kalamees, Lembit Kurik

Tallinn University of Technology (TTÜ), Ehitajate tee 5, Tallinn19086, Estonia

Abstract

The aim of this work was to evaluate the durability of selected wood-based panels according to the modified standard method D3273. Temporary wetting or storing in unfavourable conditions in different building stages initiates the growth of mould on the surface of wood-based panels due to the contamination of panels in early stages like manufacturing or transporting. The panels were tested as-they-were – no initial sterilization or particular test microorganisms were used. The tested panels showed notable growth of different types of moulds. The main mould occurred from the *Genus Aspergillus* what is considered as xerophilic. Under the optical microscope the network of fungal mycelium was detected also on panels what did not show visible growth. Environmentally friendly wood-based panels are very susceptible to the surface mould development whenever the favourable moisture conditions appear. The RH for the development of xerophilic moulds is relatively low — about 75% RH, what is rather common condition in the construction site. Surface mould, even it is not visible or actively growing, is potentially harmful to habitants. The results of this work were highly valuable to both scientists and structural engineers.

Peer-review under responsibility of the organizing committee of the 11th Nordic Symposium on Building Physics.

Keywords: Environmentally friendly wood-based panels; surface contamination; mould growth; testing ;

1. Introduction

Wood, due to its many beneficial properties, is considered as a valuable consumable and construction material. Besides solid wood, new types of wood composites have been developed; among those environmentally friendly ones are gaining interest. The term "environmentally friendly" here is used for the wood composites where the "other" ingredients (mainly polymeric) are considered to have low negative impact to human health and environment, or

* Corresponding author. Tel.: +372 620 3152
E-mail address: urve.kallavus@ttu.ee

1876-6102
Peer-review under responsibility of the organizing committee of the 11th Nordic Symposium on Building Physics
10.1016/j.egypro.2017.09.756

panels what are manufactured solely from wood. In applications, one should distinguish between these types of panels. In houses, built according to a new construction concept called “Passive House”, these materials are the most suitable and desired.

Newly built house may hide a myriad of problems originated from the quality of construction technology, materials suitability, or non-defined reasons. Building occupants may suffer from “Sick Building Syndrome” - the term what was coined by the WHO in 1986 [1]. The causes of which are probably multifactorial and it can be detected only after step-by-step elimination all other building related illnesses [2]. In many cases the real cause of the discomfort mains unsettled [3].

The problem with the materials elevated moisture starts from the contact of the surface with the source of moisture. This can be a direct contact with the water source or the contact with moist air. The main difference in these cases is only duration of contact. The equilibrium moisture content of the material accumulates over certain time causing delayed moisture damage. The surface of the materials exposed to high relative humidity of air is the main source of the moisture problems.

Optimally the humidity conditions for growth of practically all indoor fungi species are in a RH-range of 90–100%, but it is agreed by scientists that the most of indoor fungi species start a growth above 80% of RH occurring close to the surface [4]. Authors [5] divided moulds into categories according to minimal needs for the germination. Six groups were detected – highly xerophilic, xerophilic, moderately xerophilic, moderately hydrophilic, hydrophilic and highly hydrophilic. Highly xerophilic fungi needed for the start of the growth at 20 °C 75% RH what is less than commonly agreed. Additional to favourite environmental conditions the presence of food – some organic material - is necessary. Due to the fact that many mould species produce cellulolytic enzymes [6] leads to the results that wood-based construction materials are very good substrates for the mould growth without any additional actively encouraging additives.

For the development of the mould growth it is essential that mould spores land up to the surface. Potentially there is always some mould spores present what get onto the surface from the surrounding air. After manufacturing the construction material gets into contact with various indoor and outdoor environments and gains some mould onto the surface. Arriving to the construction site too early before the installation or installed into contact with other moist materials the mould growth suddenly proliferates.

Testing the potential of construction materials for the surface mould development is usually performed by following standard procedures:

- D 3274 Evaluating Degree of Surface Disfigurement of Paint Films by Microbial (Fungal or Algal) Growth or Soil and Dirt Accumulation
- D4610 Determining the Presence of and Removing Microbial (Fungal or Algal) Growth on Paint and Related Coatings
- D 5588 Determination of the Microbial Condition of Paint, Paint Raw Materials and Plant Areas

It is evident that existing standards and laboratory procedures are mainly targeted to the quality evaluation of finishing materials as the first priority of manufacturers. They are useful for validation of the critical moisture conditions for mould growth on building materials [7, 8, 9]. In 2012 a new edition of procedure to the first standard was issued D3273-12, but the main principle of the testing remained the same. In this laboratory procedure sterilized, oven-dried samples were sealed into the test chamber where the moist soil incubated with three different species of mould was placed onto the bottom. The temperature and air RH were controlled by loggers. The results were evaluated by visual inspection of developed surface mould in scale of 0-10 where the score 10 meant that mould growth was not visible. The test lasted 4 week during what regular evaluation was performed microscopically to discover early stages of mould development. This test is usually exploited for the testing of indoor coating materials like paints and varnishes. This standard procedure holds numerous shortages:

- Laboratory conditions where D3273 is applied are miles away from the real conditions at construction sites. The main shortage is the selection of three particular mould species
- In real situation, the surface of wooden construction materials is deteriorated by numerous moulds of random origin already before it arrives to the construction site
- This standard was developed in USA and singled out mould species might not be specific to other regions

- In standard procedure, the soil is not sterilized what make the test more ambiguous
- The results of the test are not well reproducible

The source of unacceptable indoor climate quality may be hidden in the improper handling of building materials susceptible to microbial attack. Particularly when the contact with water or air with high humidity is short-time and the biodeterioration act unnoticed. This can easily happen in construction site when delays between materials provision and actual installation occur and materials are temporarily stored in inappropriate conditions. Materials surface is in contact with moist air or gets wet for short time – the moisture is not penetrating deep and no dimensional changes occur. When the conditions improve or materials are moved and installed, the surface of material dries and looks again as new. Evidently there is NO PROBLEM. But is it really so?

In this research, we simulated in laboratory conditions the situation on the construction site where wood based construction plates stayed for some time in unfavourite moisture conditions and followed the development of fungal growth on the surfaces of plates.

2. Materials and methods

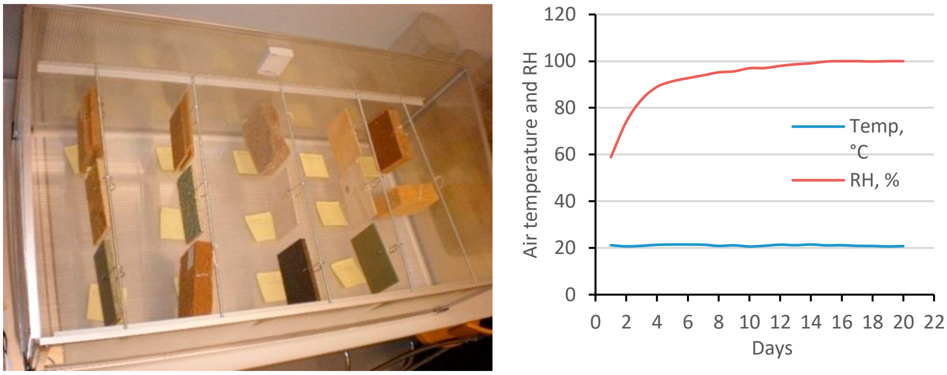
In this work, available on the market wooden construction plates were chosen what are most frequently used (Table 1.). Samples 9-13 represents the construction plates marked as environmentally friendly. To simulate moisture conditions what might occur at construction sites the test chamber was built according to ASTM standard method D3273-00 „Standard Test method for Resistance to Growth of Mould on the Surface of Interior Coatings in an Environmental Chamber" 2005. The setup of the experiment was modified according to the methodology worked out by Swedish microbiologist Aime Must. Instead of soil in the bottom of the test chamber a vessel with distilled water was placed. No test fungi were used and samples were tested as-they-were without sterilisation and oven-drying before the test. Samples were hung up with hooks from stainless steel wire leaving enough space between the plates (Fig 1a). Two sets of placement were used – vertical and horizontal to simulate possible storing or installing conditions. Test chamber was equipped with two data loggers for recording temperature and moisture in lower and upper space of the chamber. Also, the environmental conditions of surrounding environment were recorded (Fig 1b). After loading the samples test chamber was closed and insulated. To prevent the spreading of developing mould growth to neighbouring plates no air circulation was used. The chamber was checked daily and in the case of appearance of any visible mould, particular plate was immediately removed.

For the registration of environmental conditions, HOBO data loggers (temp/RH) were used. Mould surface growth was detected first visually and after with the stereomicroscope NIKON SMZ800. The identification of mould species was performed with the universal microscope NIKON Microphot FX at the magnification 400x. Ethanol (96.6°) for the disinfection of test chamber was of laboratory grade and used without further purification. Distilled water was readily used from the laboratory's own distilled water system.

Table 1. Tested samples.

No	Sample	Characteristics	No	Sample	Characteristics
	PLYWOOD				
1	Pine plywood, stored in warehouse.	For indoor and outdoor usage.	8	Moisture resistant chipboard, stored in warehouse.	Waterproof resin gluing. For usage in elevated moisture conditions.
2	Spruce plywood, stored in warehouse.	For indoor and outdoor usage.	9	Wind barrier fiberboard, stored indoors.	Highly hydrophobic. Can stand shortly in moist environment.
3	Moisture resistant birch plywood, stored in warehouse.	Waterproof resin gluing. For indoor and outdoor usage. Should be protected from direct contact with water.	10	Flexible insulation fiberboard from pinewood, stored indoors.	For indoor usage.
4	Phenolic resin film faced birch plywood, stored in warehouse.	Waterproof resin gluing. For indoor and outdoor usage. Well protected from the surface side against outdoor conditions, edges should be	11	Soft insulation fiberboard	For indoor usage.

		protected separately.		(hemp), stored indoors.	
	CHIPBOARD, FIBERBOARD				
5	Oriented strand board OSB3, stored outdoors, protected from rain.	Waterproof resin gluing. For usage in elevated moisture conditions.	12	Soft insulation fiberboard, stored indoors.	For indoor usage in contact with residual moist containing concrete flooring systems.
6	Particle board QSB, stored indoors.	Waterproof resin gluing. Highly resistant to moisture, for usage in elevated moisture conditions.	13	Fiberboard for underflooring, stored indoors.	For indoor usage.
7	Bitumen coated wind barrier fiberboard, stored outdoors protected from rain.	For usage in outdoors and moist conditions.			



(a) (b)

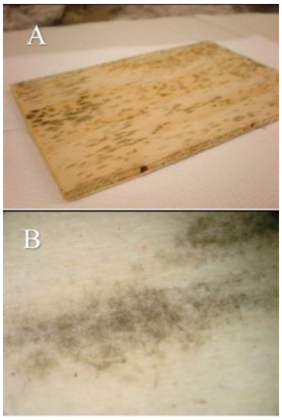
Fig. 1. (a) Vertical placement of samples; (b) Measurements of environmental conditions inside the test chamber.

3. Results and discussion

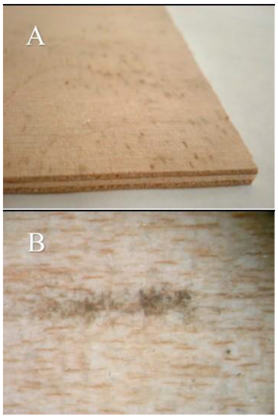
The test was intended to carry out as long as in the standard - 4 weeks. During the first week, the internal climate reached the critical RH 90% and that copied well the possible real situation (Fig 1b). At the end of the second week first signs of mould development occurred and the samples No 2, 3, 8, 10, 11, 12, 13 were removed and inspected visually (Photos A in Fig 2.) and under microscope (Photos B in Fig 2.). On the day 17 next plates No 4, 6, 9 were removed and inspected, and finally on the day 21 the last samples No 5 and 7 were removed and inspected.

As a result, up the end of week 3 all samples were covered with mould what showed that construction plates are contaminated by mould spores prior to arrival to the construction site. The main species of mould were from geniuses *Aspergillus, Cladosporium, Penicillium, Eurotium*. The first three are the most common environmental contaminant fungi [4]. In compliance with [5] the appearance of xerophilic moulds *Aspergillus spp.* and highly xerophilic *Eurotium spp.* in laboratory culture media is most evident. All these mould species are potentially harmful, when the construction plates are handled, or afterwards inside construction in the appearance of negative air pressure created by ventilation system.

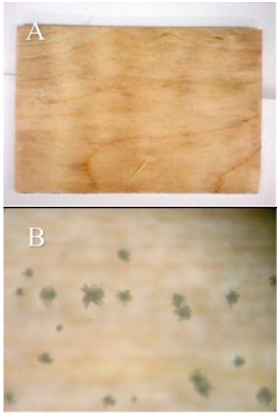
According to our testing the best performance showed wood-based construction plates manufactured from pinewood, oriented strandboard, fiberboard plates with bitumen coating and waterproof birch plywood from the sides of coated surfaces. Edges of the last plates are vulnerable and should be carefully protected from the access of moisture. Moisture resistant glue is not the guarantee against the mould damage as it was proved by the weak performance of moisture resistant birch plywood and glued with moisture resistant glue chipboard. The worst performance showed environmentally friendly wood-based panels. Even though it was actually expected due to the most vulnerable to biological attack woody material, it brings forth some cautions.



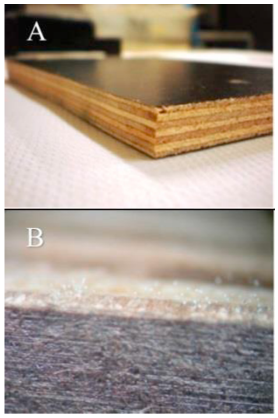
Sample No. 1 after 21 days, *Cladosporium spp*.,



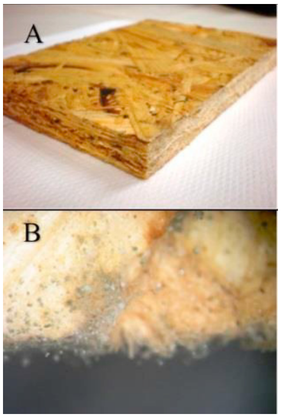
Sample No. 2 after 13 days, *Cladosporium spp*.



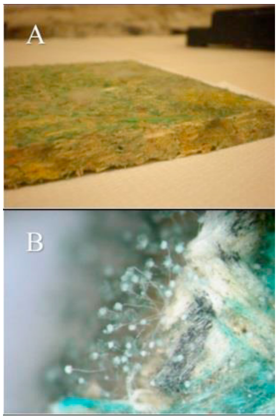
Sample No. 3 after 13 days, *Aspergillus spp*



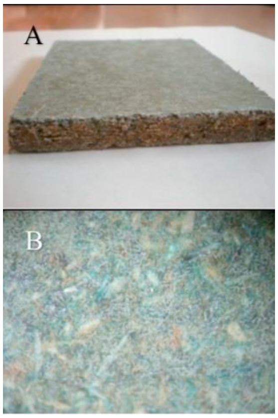
Sample No. 4 after 17 days, *Aspergillus spp*



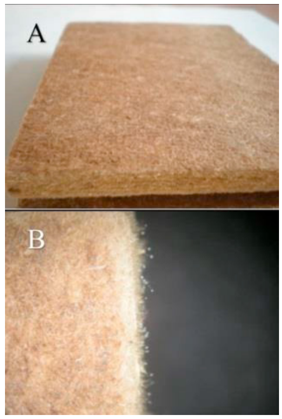
Sample No. 5 after 21 days,*Penicillum spp.* and *Aspergillus spp.*



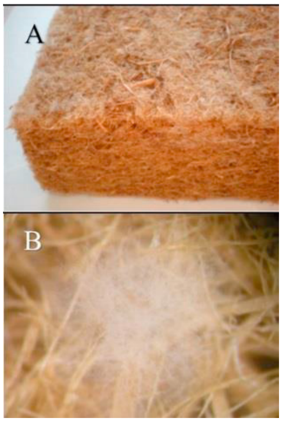
Sample No. 6 after 17 days, *Aspergillus spp.* and *Eurotium spp.*



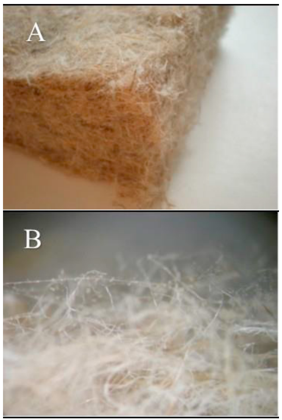
Sample No. 8 after 13 days, *Aspergillus spp.*



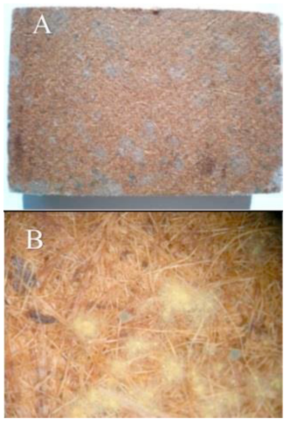
Sample No. 9 after 17 days, *Aspergillus spp.*



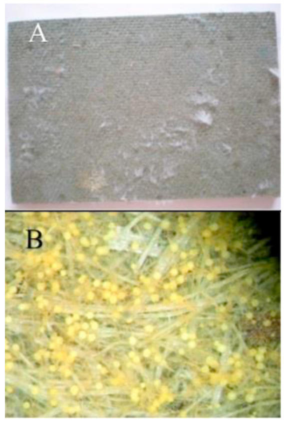
Sample No.10 after 13 days, *Aspergillus spp.*



Sample No. 11 after 13 days, *Aspergillus spp.*



Sample No. 12 after 13 days, *Eurotium spp*., *Aspergillus spp.*



Sample No. 13 after 13 days, *Eurotium spp*.

Fig. 2. Inspection of samples after the test: (A) visual inspection; (B) close-up view under the stereomicroscope.

4. Conclusions

In this work, the potential of commercially obtained samples of different types of wood-based construction panels to develop surface mould in unfavourable moisture conditions was tested. These unfavourable conditions occur easily on construction sites due to the delays in construction process when moisture sensitive materials arrive long before they are installed and are stored improperly. The information about the misuse of moisture sensitive materials and the real risks arising from that are crucial for the planning of construction activities. In addition, they provide valuable information about the new possibilities of use environmentally friendly materials, which are essential for the future users of the panels.

Growth of moulds on surfaces of building materials may result in spoilage of the surfaces, biodegradation of wood-based structures and human health hazards. Various mould fungi can be found growing on the surface of materials, most of them are common environmental contaminants. Opposite to wide spread knowledge, highly xerophilic fungi are able to grow at relatively low RH values and create surface contamination in rather common conditions at constructive sites. The physical performance of the material may not be affected, and after drying out the visible deterioration may disappear. Environmentally friendly construction panels are derived from wood with minimum processing and additional additives. Such materials are particularly vulnerable to attack by microorganisms. In handling, invisible fungal spores and hyphal fragments may be released containing a range of metabolites potentially harmful to construction workers and later inhabitants of houses. Even though the benefit of environmentally friendly panel lays in the friendliness to inhabitants and improves the indoor condition of our future houses, the misuse of these can lead to serious damages.

The results obtained in the work are of high practical value of providing information about the risks that prevail due to the improper handling of moisture sensitive materials. It should be stressed out that surface mould what is generated in moist environment due to the existence of mould spores already attached the surface along the way of travelling to the construction site, is only part of the problem. Commonly the surrounding air contains more fungal spores and after being attached to the surface they create additional biodeterioration if the RH of air is higher than 80% for longer than one week at 20 °C.

Choosing of environmentally friendly materials accompanies more attention to the conditions where these materials perform. Commonly manufacturers of such wood-based panel underline in the technical description and usage manual the vulnerability of these materials against excessive moisture. Avoiding these cautions may lead to serious failure of building material.

Acknowledgements

This research was supported by the Estonian Research Council with Institutional research funding grant IUT1-15.

References

[1] WORLD HEALTH ORGANIZATION (WHO) lndoor air quality research. EURO Reports and Studies No. 103, WHO Regional Office for Europe, Copenhagen;1986.
[2] EUR 12294 - European concerted action. Indoor air quality and its impact on man. COST Project *61* 3: Sick Building Syndrome A Practical Guide. Luxenburg; 1989.
[3] Pietrzyk K. A systemic approach to moisture problems in buildings for mould safety modelling. Building and Environment, 2015; 86:50-60.
[4] Sadovský Z, Koronthályová O. Exploration of probabilistic mould growth assessment. Applied Mathematical Modelling 2017; 42:566–575.
[5] Clarke JA, Johnstone CM, Kelly NJ, McLean RC, Anderson JG, Rowan NJ, Smith JE. A technique for the prediction of the conditions leading to mould growth in buildings. Building and Environment 1999; 34:515-521.
[6] Singhania RR. Cellulolytic Enzymes. In: Nigam PS, Pandey A, editors. Biotechnology for Agro-Industrial Residues Utilisation. Springer Netherlands; 2009. p. 371-381.
[7] Johansson P, Ekstrand-Tobin A, Gunilla Bok G. An innovative test method for evaluating the critical moisture level for mould growth on building materials. Building and Environment, 2014; 81: 404-409.
[8] Johansson P, Svensson T, Ekstrand-Tobin A. Validation of critical moisture conditions for mould growth on building materials. Building and Environment, 2013; 62:201-209.
[9] Johansson P, Ekstrand-Tobin A, Svensson T, Bok G. Laboratory study to determine the critical moisture level for mould growth on building materials. International Biodeterioration & Biodegradation, 2012; 73:23-32.