Mould Growth Experiments of Full Scale Wood Frame Wall Assemblies

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ABSTRACT

This paper reports on a full-scale experimental investigation of the mould growth on different types of wood products used for sheathing and framing wall assemblies. Objectives included examination of the difference in mould growth in full-scale wall systems under different temperature and humidity conditions for treated and untreated wood products.

Importantly this study used full scale wall assemblies; to date mould growth studies have only been performed within a laboratory on small samples of materials. Moreover, this study recreates the conditions which evidently cause mould growth on full scale wall assemblies. Tests were performed within a climate chamber on three wall assemblies. The scope of the study includes both the sheathing and framing components, but this paper focuses mainly on the sheathing.

Results indicate that the relative humidity conditions needed for mould growth to occur on wood in a reasonable time (less than several months) are higher than a surface relative humidity of 80%RH. During the first eight weeks of one test, the conditions at the surface of the sheathing was held constant at 26 ºC and 95%RH and little mould growth was observed on the untreated sheathing and little or no mould growth was seen on the borate-treated sheathing. The other tests demonstrated that the presence of liquid water greatly reduced the time to germination, the amount of mould growth, and the rate of mould growth. All three tests clearly showed that borate treatment reduced the amount of mould growth; however, the concentration of borate treatment, and the types of materials treated, does influence the resistance of mould growth. Furthermore, there was some evidence to suggest that borate treatments of the plywood increased the time to germination significantly, from a few weeks to 16 weeks in this study, but once mould growth was initiated, the rate of mould growth was similar to that of the untreated plywood.

Recommendations include improvements to the test method and for future work.

INTRODUCTION

Most North Americans spend more than 90% of their natural lives indoors and the environment within those buildings affects the occupants' health, quality of life, and productivity (Laporte et al 2005). Some buildings have problems with indoor air quality (IAQ). The IAQ of a building can be compromised by airborne microbial contaminants such as mould, bacteria, chemicals, or allergens. Poor IAQ has been found to affect the health and productivity of the occupants; this negative effect has been referred to as "Sick Building Syndrome" or "Building-Related Illness". According to the US Environmental Protection Agency (EPA) and the World Health Organization, 30% of new or renovated homes have indoor air quality problems (United States Environmental Protection Agency 1995) and according to the Occupational Safety & Health Administration (OSHA) 20% to 30% of office building are "sick" (Occupational Safety and Health Administration 1994). Mould growth that is air connected to the indoor environment has become a major and highly publicized IAQ concern.

WHAT IS MOULD

Mould, are classified as part of the fungi kingdom. Fungi are organisms which do not produce carbon through photosynthesis but obtain it from organic compounds (i.e heterotrophic). Fungi absorb their food rather than ingesting it, which sets them apart from the animal kingdom. Millions of fungi species are estimated to exist, but only a fraction of them have been well identified and catalogued (Armstrong and Liaw, 2002).

MOULD GROWTH

Mould growth requires oxygen, spores, temperature, nutrients and moisture (Figure 1). Oxygen is required for fungal growth, but is usually abundant regardless of design. As mould spores exist in the outdoor air in significant concentrations and, given the resiliency of mould, it can safely be assumed that some mould spores can be found on essentially all building materials, it can be assumed spores are always available. The nature of these spores varies widely. Ideal temperature conditions for most mould species are in the range of normal room temperatures. For most mould, the growth rate outside of this range is much slower -- below 5°C and above 50°C very little mould growth occurs. In most buildings the nutrients which support mould are readily available, as many building materials are organic or are produced from organic products, such as: paper, glue, paints, textiles, ceiling title, furniture fabric, etc. Fungi excrete enzymes to break down their food outside their bodies. In order for the digestion process to proceed, a certain amount of moisture is required on the substrate being consumed. This moisture may be present from moisture built into the substrate, from high surface relative humidity, condensate, rain, or ground water.

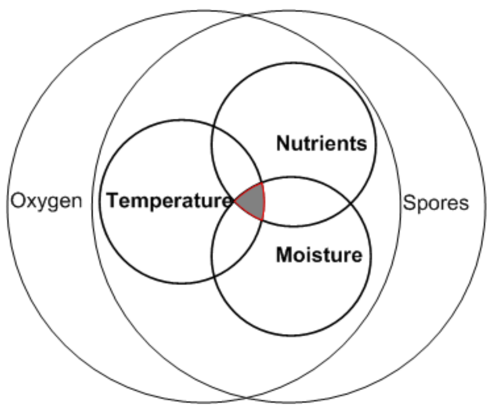

Figure 1: Mould Growth Requirements (OAA 2003)

CONTROLLING MOULD GROWTH

Controlling mould by removing the source of moisture is part of the already accepted practice of moisture control (OAA 2003). Some of the important methods employed to control moisture include the proper control of rain penetration via flashings and drains, the regulation of temperature and humidity within a building enclosure at critical surfaces, the maintenance of plumbing and HVAC systems, and the selection of materials appropriate for the temperature and moisture conditions that can be expected during service. There are a number of different products available which can replace organic compounds (i.e. food) with one those that have little or no food value. Another method for preventing mould growth on products composed of organic compounds is to render the organic compounds unappealing to mould. Chemicals used for the purpose include CCA, ACA, and borate. Borates are naturally occurring salts which result from the combination of oxygen and boron. Borates are often chosen because of for their low mammalian toxicity (it is for this reason that they are widely used in many household products such as detergent, cosmetics, ceramics, and medicines). This paper focuses on the mould growth on both untreated and borate-treated plywood and OSB.

PREVIOUS RESEARCH

Based on more than a decade of international research (IEA 1991 ,Clarke 1999, Hens 2000) it has become commonly accepted that the lower threshold for the onset of mould growth is around 80%RH at temperatures over 5 °C. As the RH climbs and the temperature nears the optimum value around 25 °C, the time to germination decreases and the rate of growth accelerates. The 80%RH threshold has also been chosen as the highest safe level for wooden materials in the proposed ASHRAE 160P standard. This is a conservative value appropriate for steady-state conditions. Adan (1994) found that in non-steady conditions, the time of wetness (TOW) above 80% played a strong role in mould growth.

Most of this earlier research investigated mould growth on agar-like substrates dosed with mould spores in aqueous suspensions. This approach provides both liquid water and an excellent food source for the single mould species being tested. This limits the practical application of the information, as building scientists work with building materials as food sources, do not control what mix of spores are present, and avoid exposing many materials to liquid water. Doll (2002) conducted a series of experiments on small scale samples of building materials to overcome these practical limitations. She demonstrated that untreated building materials from local suppliers always contained mould spores. However, she found that relative humidity levels much higher than 80% where required to initiate meaningful quantities of mould growth.

DESCRIPTION OF EXPERIMENT

A research program was developed to extend Doll's well-known work. That is, no mould dosing was used (hence avoiding liquid water) and humidity and temperature imposed. A unique feature of this experiment was the use of full-scale wall assemblies exposed to gradients of relative humidity and temperature. This is very different than previous studies which performed small scale material testing within a laboratory under stable and uniform conditions. The project was not large enough to attempt the generation of a predictive model, but was intended to provide data and insight for researchers and practitioners.

The objective of the experimental work was to investigate mould growth on wood products in extreme conditions (ideal moisture and temperature conditions), and the impact of borate treatment.

A climate chamber was first constructed to tightly control the relative humidity and temperature conditions. Several full scale test wall assemblies were then constructed and instrumented to measure the conditions within the assemblies. One commissioning and three test series were completed. Although the commissioning test was used to demonstrate and commission the experimental procedure, it did yield interesting and useful results. Several different wall assemblies were tested under different steady state and varying conditions in order to meet the experimental objectives.

Within this study three types of dimensional lumber and two types of sheathing were tested. The emphasis of this paper is on the sheathing and not the dimensional lumber. The dimensional lumber types tested included Southern Yellow Pine, Spruce Pine Fir, and Douglas-Fir . The types of sheathing tested were Oriented Strand Board (OSB) and Southern Yellow Pine (SYP) plywood. All five types of wood products were tested either as untreated or borate treated. The OSB contained about 0.91% boric acid equivalent (BAE) while the plywood contained 1.44% BAE. More details of the wood products and the treatment can be found in Black (2006).

TEST WALL PANEL DESIGN

The test wall was designed and constructed to match standard construction for the framing and sheathing as closely as practical, but the primary goal was to produce well characterized temperature and RH conditions at the inside face of the sheathing. The use of full scale wall assemblies allowed for more realistic testing but implies that small variations between locations within the assembly would be created by the gradients formed by differential temperature and vapour pressures. We hoped to learn the significance of these small variations. Within each test wall assembly treated and untreated versions of the following products were used: OSB, plywood, douglas-fir, Spruce Pine Fir (SPF), and Southern Yellow Pine (SYP). The wall assembly was framed using 2" x 4" lumber, insulated using unfaced R13 glass-fibre batt insulation in the stud space. The sheathing was then placed on the exterior side of the wall assembly. Spun-bonded polyolefin (SBPO) was used on the interior side to airseal the wall assembly in lieu of gypsum wall boards to avoid mould growth on the paper facing under the relative humidity conditions of the test. The vapour resistance and thermal resistance of SBPO is very low, much like gypsum board. As mentioned previously the care taken to avoid air leakage ensured that the only method of water vapour transport through the test wall assembly was by diffusion.

Two test panels were used per test series to allow for the maximum number of material test combinations while accommodating for redundancy within the wall design. The dimension of each test panel was 4' x 8' and these panels were divided into quadrants to maximize the combinations of different variables that can be tested (Table 1, Figure 2, and Figure 3). The sheathing used in each quarter was alternated between plywood and OSB. To reduce convective loops within each quarter, wood blocking was used as a separator. Each type of sheathing was located with an upper and lower quadrant to determine the influence location may have on the outcome.

Table 1: Experimental Matrix for Sheathing

Quadrant	Product	Treated	Location
1	OSB	Yes	Upper
2	Plywood	Yes	Upper
3	Plywood	Yes	Lower
4	OSB	Yes	Lower
5	Plywood	No	Upper
6	OSB	No	Upper
7	OSB	No	Lower
8	Plywood	No	Lower

Within each of the two test panels the three types of sawn lumber were tested. Furthermore, each test panel was tested in a side-by-side comparison of untreated and treated samples. To avoid edge effects, no studs were tested on either side of the test panels (perimeter of climate chamber), which created a "guard bay". To accommodate the number of samples the studs were spaced at approximately 12" on center.

During each test the mould growth on each wall assembly was visually inspected from time to time to quantify the extent of mould growth. Each quadrant has a test port measuring 2' wide by 1' high which allows for its removal allowing for the examination of mould growth as well as inspection of all samples within the wall on a regular basis. A photo of each test port was taken on a regular basis. The test ports were placed on a fixed support to ensure repeatable photographs throughout the experiment that allowed for better comparisons.

Each panel was instrumented with electrical resistance pins (for moisture content measurement) temperature sensors (0.2 ºC accuracy thermistors), and capacitance-based relative humidity RH sensors (2% RH NIST traceable). Details are in Black (2006). The temperature at the back of the sheathing is the variable of critical interest for mould growth. As an RH sensor would change the thermal properties around it if placed at the sheathing surface, we instead located the sensor within the highly vapour permeable batt insulation. Using the vapour pressure measured at the RH sensor, and the sheathing surface temperature measured from the small thermistors, we can calculate the surface RH with very good accuracy by using the knowledge that the vapour permeance of the batt is constant across its thickness. Also, an RH sensor located in 95%+ RH environment will neither be accurate or durable. By deliberately imposing a thermal gradient, we can accurately measure the vapour pressure with the RH sensor in the batt (at 70-80%RH) and at the surface of the sheathing while near condensing conditions.

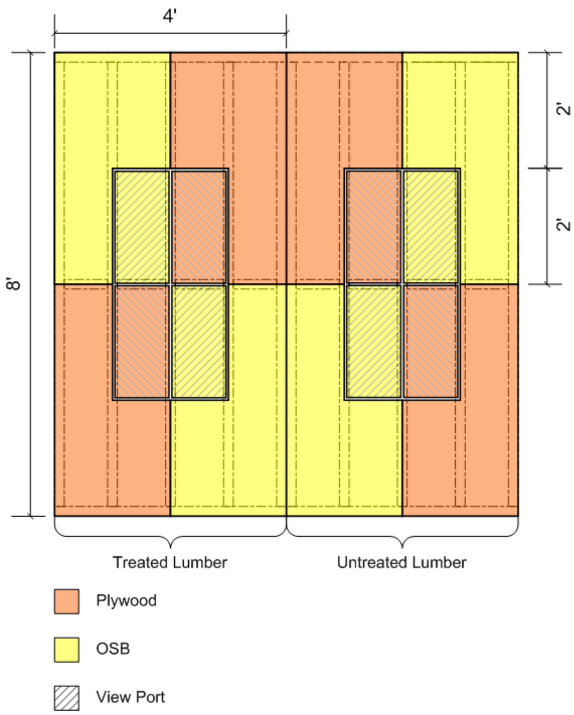

Figure 2: Sheathing Layout of Two 4' x 8' Test Panels

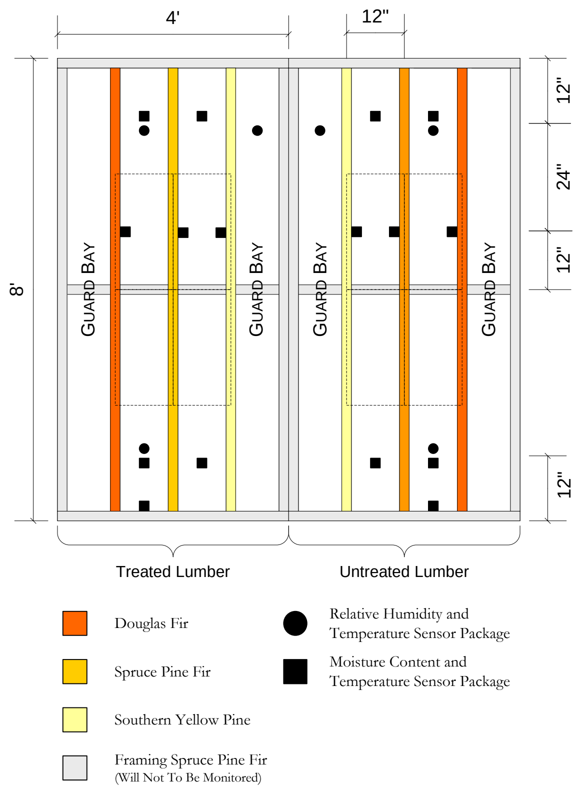

Figure 3: Test Panel Stud Framing Layout and Sensor Locations

Four tests were performed. The first was a commissioning test and the remaining three tests were used to meet the objectives of the study. Target temperature and surface humidity conditions were defined at the interstitial-facing side of the sheathing. The three target boundary conditions, arranged in chronological order, were:

Test Number 1:	Constant 26 °C and 95% (Figure 4).
Test Number 2:	Prolonged condensation conditions (Figure 5) at 26 °C until the moisture content equilibrates, after which the RH is lowered to 95% (Figure 4).
Test Number 3:	Fluctuating condensation conditions: 8 hours of condensation conditions (Figure 6) at 20 ºC, followed by 16 hours at 30º C and 80% RH (Figure 7).

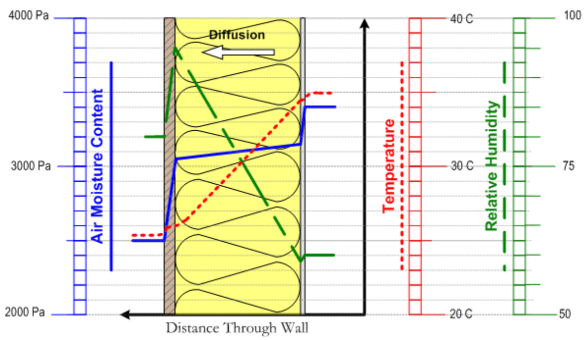

Figure 4: 26°C & 95% Relative Humidity at Back of Sheathing

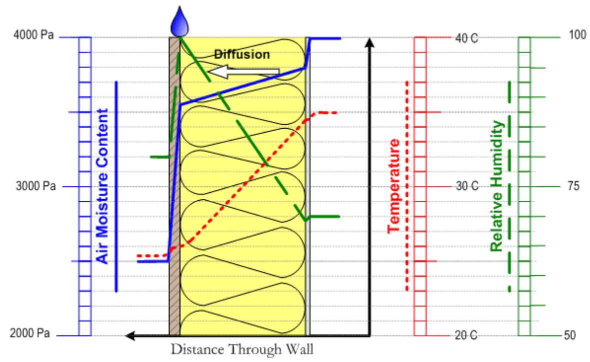

Figure 5: 26°C & Condensation Conditions at Back of Sheathing

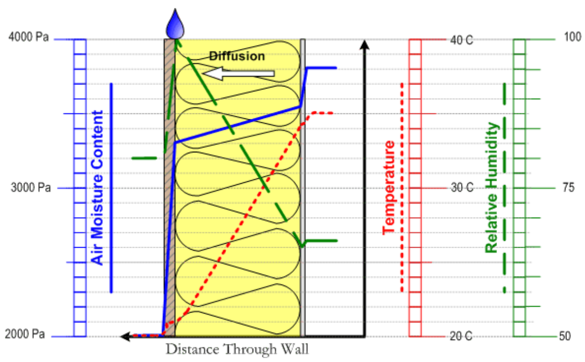

Figure 6: 20°C & Condensation Conditions at Back of Sheathing

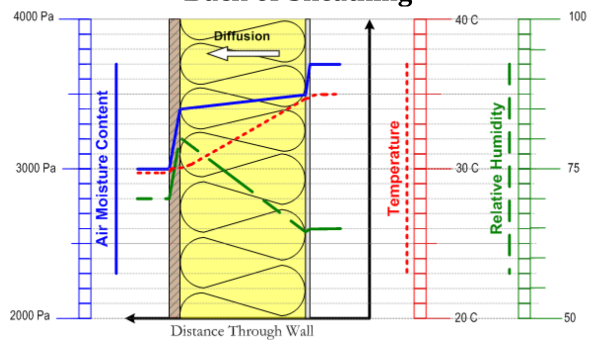

Figure 7: 30°C & 80%Relative Humidity at Back of Sheathing

Chamber Commissioning Test

A commissioning test was undertaken to determine the effectiveness of the equipment in controlling the conditions within the climate chamber and test panels. Only standard framing lumber (3/8" plywood and standard OSB from local suppliers) was used in the commissioning test panels. The commissioning test began on August 9, 2004 and ran until September 30, 2004.

During the inspection of the test ports on September 7, 2004, extensive mould growth was observed on the test ports along with the observation of liquid water. Early on during the commissioning test the relative humidity at the back the sheathing at some locations exceeded 100%, and therefore condensation conditions existed. Hence, the mould growth observed was likely the result of this highly favourable (for mould growth) condition. The thin plywood panel experienced little or no condensation because its permeance was significantly higher than the adjoining OSB panel and hence the surface RH did not reach 100%. This difference in permeance required that the multiple layers of Tyvek be used on the interior to limit flow into the OSB panel, and thereby reach equal levels of relative humidity at the back of both the OSB and plywood.

Test Number 1

The first of the planned climate chamber tests began October 13, 2004, and was completed on February 23, 2005, a duration of 19 weeks. A timeline for the conditions in the interior side of the climate chamber can be seen in Figure 8.

Test Number 1 has been broken into 6 major events. For the entire test the climate side of the climate chamber was maintained at 25ºC and 80% RH, and the temperature of the interior side of the climate chamber was maintained at 35ºC. From October 13, 2004, to December 8, 2004, the relative humidity of the interior side climate chamber was varied in an attempt to produced 95% relative humidity conditions at the interstitial-facing side of the sheathing. On December 8, 2005, the interstitial facing side of the sheathing conditions stabilized at approximately 95%. These conditions were achieved by maintaining the interior side of the climate chamber at a relative humidity of 53.5%. These conditions were maintained until January 4, 2005. At this point it was decided the test was not achieving its original goal of demonstrating mould growth in a reasonable time. To promote growth, on January 4, 2005 the relative humidity on the interior side of the climate chamber was increased until condensation conditions were reached on the interstitial-facing side of the sheathing. These conditions were maintained until January 17, 2005, when the relative humidity conditions in the interior side of the climate chamber were again lowered to 53.5%. These conditions were maintained until February 4, 2005, at which point condensation conditions were imposed on the interstitial facing sheathing conditions and maintained. On February 16, 2005 the conditions at the interior side of the climate chamber were lowered to 53.5% for the remainder of the test which was completed on February 23, 2005.

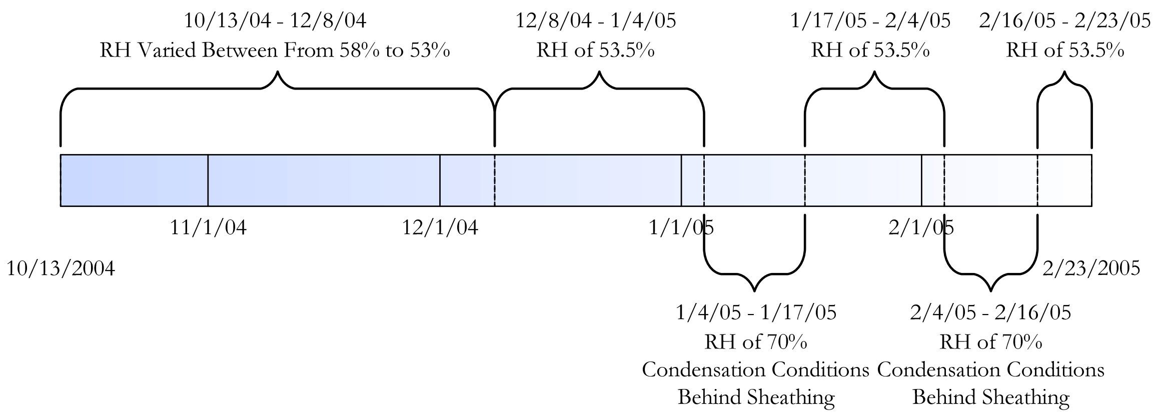

Figure 8: Timeline for Test Number 1 – Relative Humidity Conditions on Interior Side of the Climate Chamber (Climate Side Maintained at 26ºC and a Relative Humidity of 80%)

TEST NUMBER 2

The second of the planned climate chamber tests began March 9, 2005 and was completed on Monday July 11, 2005, a duration of 18 weeks. A timeline for the conditions in the interior side of the climate chamber is presented in Figure 9.

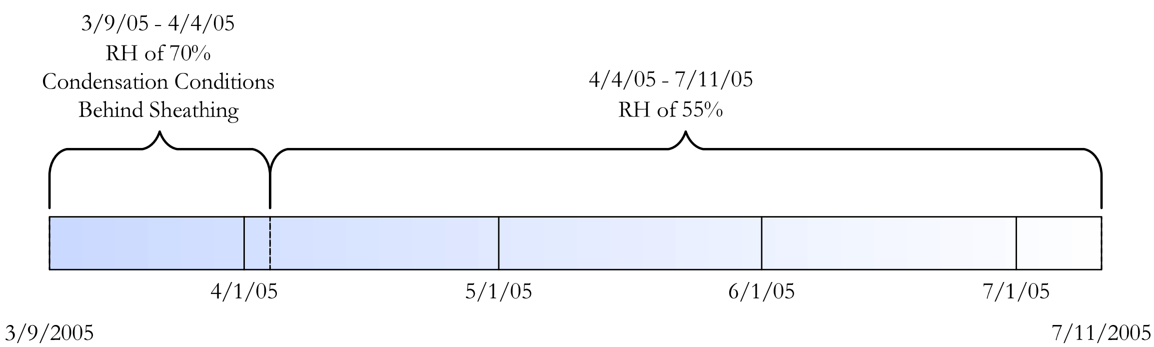

Figure 9: Timeline for Test Number 2 – Relative Humidity Conditions on Interior Side of the Climate Chamber (Climate Side Maintained at 26ºC and Relative Humidity of 80%)

Test Number 2 was broken into 2 major events. For the entire test the climate side of the climate chamber were maintained at temperature of 25ºC and 80% RH, and the temperature of the interior side of the climate chamber was maintained at 35ºC. From March 9, 2005, to April 4, 2005, the interior side climate chamber was maintained above a relative humidity of 70% to produce condensation on the interstitial side of the sheathing until the moisture content of the sheathing stabilized. On April 4, 2005 the moisture content of the sheathing stabilized and so the relative humidity on the interior side of the climate chamber was lower to 55% for the remainder of the experiment.

TEST NUMBER 3

The third of the planned climate chamber tests began September 28, 2005 and was completed on January 15, 2005, a duration of 16 weeks. For the entire test the conditions on the climate side of the climate chamber conditions were maintained at a temperature of 35ºC and a relative humidity of 67%. Unlike the previous tests the interior conditions were varied throughout. From September 28, 2005, to January 15, 2005, the temperature and relative humidity on the interior side of the climate chamber was varied on a daily basis between 20ºC and 30ºC degrees, and 80% and 70%RH respectively. Hence, for 8 hours of each day the conditions at the back of the sheathing were maintained at 20ºC and 100% RH and 30ºC and 80% RH for the remaining 16 hours.

SMALL SCALE MOULD GROWTH STUDY

A few small-scale material samples were placed in the climate side of the chamber during test number 2 to investigate the effect of the 80%RH and 25ºC conditions on mould growth. The samples included treated and untreated samples of all three types of dimensional lumber, treated and untreated OSB and plywood, drywall, white bread, and pumpernickel bread.

All thirteen samples were placed in the climate side of the chamber on November 25, 2004. Mould started to grow after one week on the pumpernickel bread and after two weeks on the white bread. After 2 months none of the building material samples showed any visible signs of mould growth.

Although mould may begin growing on excellent food value substrates under conditions of 80%RH and 25 ºC, these tests suggest that it will take much more than 2 months for common building materials. Hence it can be concluded that a 80%RH threshold is very conservative. Of course, it is unlikely that the RH would remain this constant in most real buildings. Furthermore, the testing of products with high food value (such as bread with no preservatives) supports the contention that mould spores occurs naturally within the environment and inoculation is not necessary. The different behaviour of the two samples of bread demonstrates that not all organic products are the same – preservatives can reduce the food value. Therefore, when comparing mould growth potential on different building products, care must be taken to precisely differentiate the products in question. Hence, it should be expected that different species of wood, wood grown in different locations, and wood products produced using different techniques will all have a different response to moisture and mould growth.

RESULTS

VISUAL INSPECTION

During all three tests careful visual inspections of each of the eight test ports were performed. Visual methods were chosen as visual inspection is common in the field, and most serious mould concerns are the result of visible (not microscopic) mould growth. The results were quantified using the mould index developed by Hukka & Viitanen (1999) and Viitanen et al (2000) (Table 2). Figure 10 thru Figure 15 plot the mould index (bars: left axis) and uncorrected moisture content (line: right axis) of each test port versus the time in weeks from the start of each test. Table 3 is the legend for Figure 10 thru Figure 15. The electrical resistance moisture content readings presented are not corrected. Samples have been taken and correlation coefficients are being developed. Although this work is not yet complete, initial results indicate that the uncorrected MC will be within 5% of the corrected MC.

DIMENSIONAL LUMBER

The focus of this study was on the sheathing and its mould growth resistance. However, both the sheathing and the dimensional lumber were examined. No mould growth was observed on the dimensional lumber, even around the edges of the test ports where the sheathing was in contact with framing. There are several theories as to explain this lack of mould growth. First the studs were slightly warmer (due to thermal bridging) which resulted in a lower surface relative humidity (or non-condensation conditions). Perhaps as importantly, solid wood could simply be more resistant to mould growth than OSB and plywood. A small, but theoretical benefit would be provided by the higher framing safe storage capacity.

TREATED VERSUS UNTREATED SHEATHING

The measured moisture contents of the treated OSB and untreated OSB were very similar, however, the moisture content of the treated plywood was higher than the untreated. This may be a result of the plywood being treated with preservative using a different process than the OSB. Both treatments may influence the electrical resistance of the wood, as the salts usually add conductivity. Measurement of this effect is on-going.

Table 2: Mould Growth Scale (Hukka & Viitanen 1999)

0	no growth
1	some growth detected only with microscopy
2	moderate growth detected with microscopy (coverage more than 10%)
3	some growth detected visually
4	Visually detected coverage more than 10%
5	Visually detected coverage more than 50%
6	Visually detected coverage 100%

Table 3: Legend for Figure 10 thru Figure 15

	Location	Moisture Content	Mould Index
Treated	Upper		
	Lower		
Untreated	Upper		
	Lower		

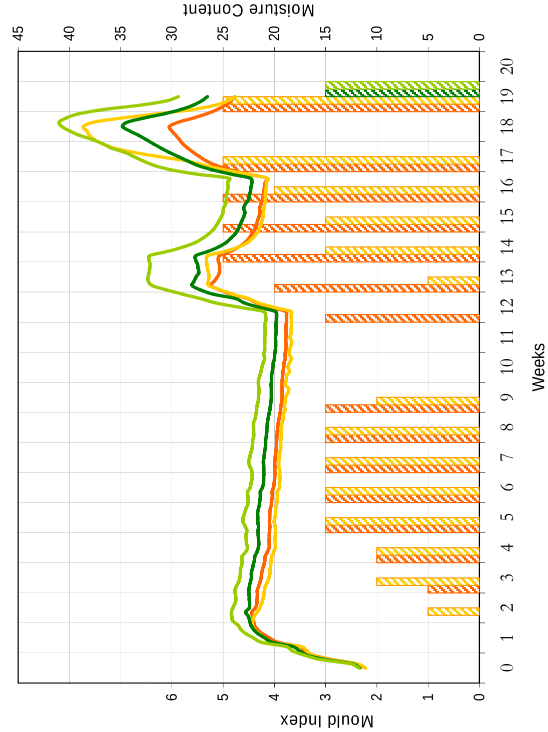

Figure 10: Plywood in Test Number 1

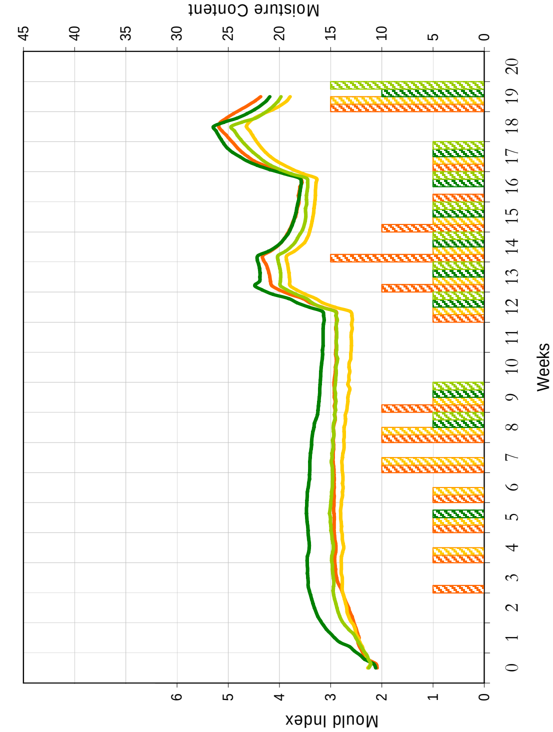

Figure 11: OSB for Test Number 1

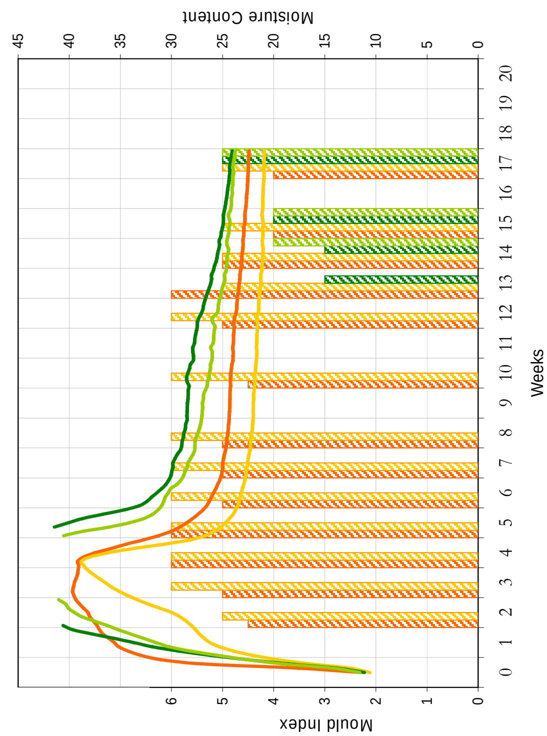

Figure 12: Plywood in Test Number 2

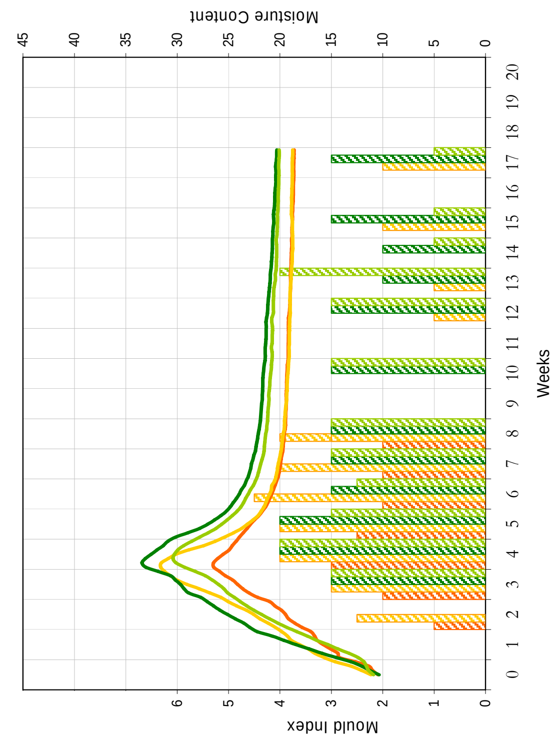

Figure 13: OSB in Test Number 2

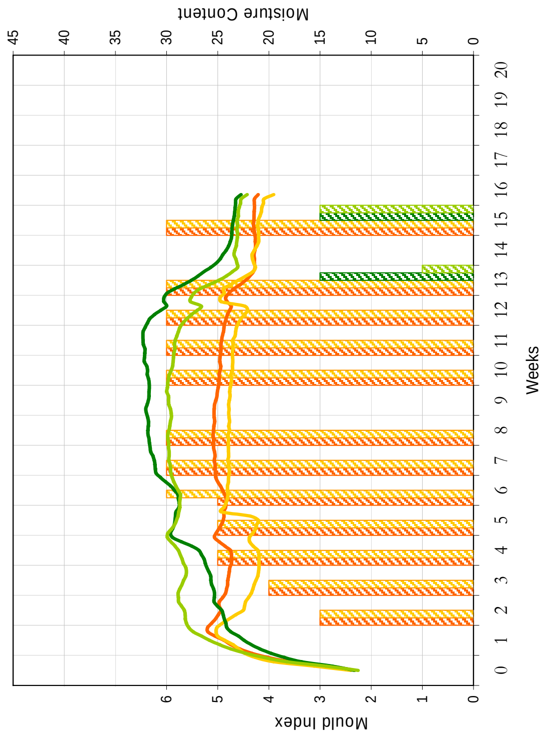

Figure 14: Plywood in Test Number 3

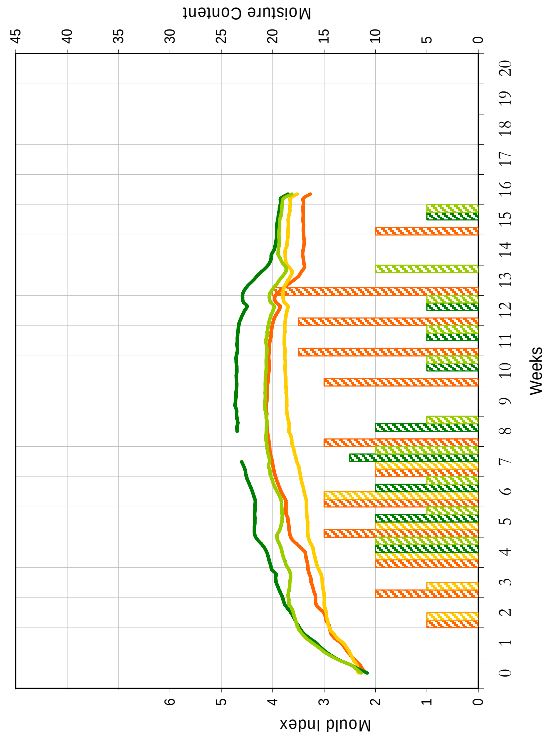

Figure 15: OSB in Test Number 3

The OSB and plywood must be discussed separately when examining the difference in mould resistance between the untreated and treated sheathing. The treated and untreated OSB performed fairly similarly with a tendency for the treated OSB to resist mould growth better than the untreated OSB. When examining the mould resistance between treated and untreated plywood it was clear the treated plywood had a much higher mould resistance than that of its untreated counter part. From these results it can be concluded that the treated plywood is an effective treatment, however, either the treatment used for the OSB is not as effective or a higher concentration of treatment is needed. As found by Li (Li 2005) higher levels of borate may be needed in OSB products to increase mould resistance significantly.

A comparison of Figure 10 (Test Number 1), Figure 12 (Test Number 2), and Figure 14 (Test Number 3) suggests that the borate treatment of the plywood increased the time to germination significantly. However, once mould growth was initiated, the rate of mould growth is similar to that of the untreated sheathing. There is not sufficient evidence for this to be a firm conclusion, and further study is recommended.

ORIENTED STRAND BOARD VERSUS PLYWOOD

When discussing the difference in mould resistance between untreated and treated sheathing it was also necessary to discuss the OSB and plywood separately, moreover, when discussing the difference between OSB and plywood it is necessary to examine the treated and untreated sheathing separately. Only the untreated samples will be discussed to remove the effect that the differences in treatment types have on the samples.

Comparing the moisture content of OSB and plywood based on the resistance of the wood poses additional problems because the material properties of OSB and plywood are very different. For example OSB is denser than plywood and is less permeable and takes longer to reach moisture equilibrium. The core gaps in the core veneers of the plywood may lead to a large increase in resistance depending on the orientation of the pins relative to the grain in the core. The lathe checks in plywood increase the likelihood that resistance will be higher across the grain and will more easily allow water to move around once past the face veneer. During the OSB manufacturing process the cell walls are crushed or damaged which inhibits the flow of water through the OSB. Furthermore the density of OSB is higher which also slows the movement of moisture throughout the OSB.

The above differences in OSB and plywood explain the difference in lag of moisture content when comparing OSB and plywood. These differences also explain the difference in the observed moisture contents which were based upon the wood resistance readings. This behaviour has significant practical implications. Currently reliable moisture content correction factors do not exist for OSB or plywood. Moreover, for the conditions which the sheathing was exposed to during the tests, reliable correction factors may not be possible. Once fibre saturation has been exceeded reliable correction factors are not possible and only trends can be examined (Onysko 2006).

Despite these differences, the relative humidity and temperature conditions which the OSB and plywood sheathing were exposed to are effectively identical. For the same RH conditions our results show that plywood is capable of supporting a much higher growth rate than that of OSB. However, in this study the flow of vapor to the plywood needed to be reduced by the addition of layers of spun-bonded polyolefin to achieve the same RH as the inside of the OSB. In the same use in the field, the higher permeance of the plywood would result in lower RH at its surface than an equal wall with OSB. Under high humidity and condensation conditions, the increased capillary flow capacity of the plywood may have aided the transport of dissolved borate salts away from the condensation surface and into the core. Clearly, many more tests should be run with different test wall assemblies to investigate the mould growth resistance of plywood versus OSB in the same application or when the assembly is exposed to the same boundary conditions.

UPPER QUADRANT VERSUS LOWER QUADRANT

During the three tests the moisture content of the upper quadrants were higher than that of similar lower quadrants, however, some exceptions to this trend can be found. Additionally, the mould growth rate was similar between the upper and lower quadrants when examining similar sheathing products. From these results it can be concluded that no excessive moisture was condensing on the sheathing and running down the sheathing. If run down was occurring higher moisture content readings would have been observed on the lower quadrants when compared with the upper quadrants.

CONCLUSIONS

Tests performed on smaller samples of wood, drywall, and wood products at a relative humidity of 80% and a temperature of 25°C showed no mould growth after 2 months. Hence the relative humidity conditions needed for mould growth to occur in under two months on wood and wood products are higher than assumed in widely circulated sources such as the proposed ASHRAE Standard 160P and IEA Annex 14 (i.e., significantly greater than 80%RH even at warm temperatures). Over two months little mould growth was observed on the untreated sheathing and little or no mould growth was observed on the treated sheathing even at constant 26 ºC and 95%RH conditions. Subsequent tests demonstrated that the presence of liquid water at 26 ºC reduced the time to germination and the time to visual mould coverage (to a few weeks).

Visible mould growth did not form on the solid wood framing during any of the tests, even under the worst conditions. Although the tests were only 16 to 19 weeks long, decay was also not observed in the sheathing in any of the tests, even those which subjected the sheathing to moisture contents of well over 30% for months.

All three tests clearly showed that borate-treatment reduced the amount of mould growth; however, the concentration of borate-treatment, and the types of materials treated, does appear to impact the resistance to mould growth. As found by others, higher levels of borate may be needed in OSB products to increase mould resistance significantly.

The study results suggest that the borate treatment of the plywood increased the time to germination significantly. However, once mould growth was initiated, the rate of mould growth was similar to that of the untreated plywood.

RECOMMENDATIONS

To improve the accuracy of the measured moisture contents and allow for the better comparison between the different types of wood products the resistance readings used to calculate the moisture content should be calibrated depending on the type of wood product being analysed. Therefore, a study should be performed to determine the correction factors for treated and untreated plywood and OSB of various species. Furthermore, the effect of borate treatment on electrical resistance of wood needs to be better understood. As electrical resistance readings require calibration correction curves which lose accuracy at high moisture contents, gravimetric measurements are recommended in future lab tests.

Additional tests should be performed for OSB and plywood with a higher concentration of borate treatment and with other treatments. A wider range of temperatures and relative humidity should be tested to expand our understanding of their impact.

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