Moisture Related Properties of Oriented Strand Board (OSB)

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TT3-136

ABSTRACT

The objective of this Ph.D. research project is to determine how various Oriented Strand Board (OSB) production parameters and physical panel properties affect the moisture-related performance of OSB. The study also looks at the various component layers of OSB individually since the material is non-homogenious and each layer behaves quite differently. The permeability of individual layers as well as the composite section were evaluated under various moisture conditions including following cyclic wetting and drying. The trial panels for this project were specifically manufactured in a commercial OSB mill, under controlled conditions. The panels were then tested in the laboratory for water vapor permeance and sorption through five relative humidity gradient steps. The outcome of this work will serve to facilitate the design of durable, healthy, energy efficient homes with OSB, and to allow the OSB manufacturer to produce a product with optimum moisture performance properties.

KEYWORDS

OSB, moisture, durability, permeance, relative humidity.

1 INTRODUCTION

Oriented Strand Board (OSB) is a structural wood composite panel product, made from wood strands, bonded together with a synthetic resin under heat and pressure. OSB comes in the form of sheets, most commonly 4-foot (1220 mm) by 8-foot (2440 mm) and a range of thicknesses from ¼” (6.5 mm) up to 1.5”(38 mm), and is used primarily for residential or lightweight construction.

Although North American wood frame houses perform very well in a wide range of extreme climates, they do occasionally experience moisture-related problems. The problems, which may cause health problems, can range from mould and mildew infestation, to buildings having extensive structural damage (Straube, 1998). Much of the residential wood frame construction in North America uses OSB for sheathing of walls (56%), floors (65%) and roofs (72%) in ever increasing amounts (24.7 billion board feet in 1993, increased by approx. 100% since 1994, (APA 2003)). Given the widespread use, OSB is often unjustly blamed for many of the problems. Since Canadian OSB production in 2003 accounted for 37% of the total global production ($2.4 billion USD), OSB is a vital value added product of the Canadian forest industry. A fundamental understanding of the moisture-related properties of OSB and how they relate to manufacturing is needed in order to protect and expand the industry.

The two main areas where an understanding of the moisture related properties are essential are in the design of buildings and in the manufacture of the building materials. The key moisture-related hygroscopic material properties are permeance and sorption. Water vapour permeance is defined as “the timed rate of water vapour transmission through unit area of flat material or construction induced by unit vapour pressure difference between two specified surfaces, under specified temperature and humidity conditions” (ASTM E96-95). In other words, permeance is a measure of the water vapour flux through a given thickness of material, due to the mechanism of water vapour diffusion. Permeability is the arithmetic product of permeance and thickness. Sorption, the combined effect of absorption and adsorption, is a property which relates the amount of moisture which a material will store, to the specific relative humidity and temperature of the environment. This study aims to determine what are the permeance and sorption properties of various compositions of OSB, and specifically how these are related to the manufacturing parameters in the OSB mill. Although sorption properties were measured, they will not be dealt with in this paper.

2 METHODS

2.1 Test Panel Manufacture

The trial panels were specifically manufactured for this project at a commercial OSB mill under controlled conditions. All of the relevant mill conditions were carefully controlled and documented while the parameters to be investigated were varied one by one. Research experience has repeatedly demonstrated that panels made on a small scale laboratory press behave quite differently from commercial panels for a number of reasons, such as differences in internal gas pressure, resin distribution, resin addition level and the way in which the mat is formed. The mill-made panels have the same properties and hence they will behave as the real commercial panels.

The panels were all made during a one-day mill trial. The panel thickness and grade chosen for the project was 7/16” (11 mm) PRS (performance rated sheathing). This is the most common panel made in industry since it can be used for the largest range of applications, from wall sheathing to roofs.

The trial panels were made on a 9 foot (2.74 m) by 24 foot (7.31 m) , twelve opening multi-daylight press, with a 153 second pressing time at approximately 205^{o}C. The surface resin was a liquid phenol formaldehyde made by Borden, and the core resin was a methylend diphenyl di-isocyanate supplied by Huntsman Polyurethanes Inc. The wax was a Borden emulsefied wax. The species mix at the time of the trial was 60% aspen (Populus tremuloides), 30% lodgepole pine (Pinus contorta), and 10% birch (Betula papyrifera). The core and surface strands were dried to approximately 2% and 3% moisture content respectively before the addition of resin and wax.

The variables selected for this study (Figure 1) were: Panel density; resin content; and surface treatment. Preliminary research indicated these were likely to have the largest impact on permeance and sorption properties, and these were variables which are controllable at the mill. The standard density of a 7/16" PRS grade panel varies greatly in the industry, so the average of 39.0 lbs/ft^3 (626 kg/m^3) was chosen as the mid point or control density for the study. Without varying any other factors, and at a standard resin and wax addition rate, three runs varying only target density were made at 34.5 lbs/ft^3 (554 kg/m^3), 39.0 lbs/ft^3 (626 kg/m^3) and 42.9 lbs/ft^3 (689 kg/m^3). Next, density was returned to the control level at 39.0 lbs/ft^3 (626 kg/m^3), and the resin addition in the surface and core layers was raised to the upper limit. The final variable to be adjusted was the surface treatment, or, in other words, whether or not the panel was sanded after being pressed. This was done again at the standard density and resin and wax settings. At least three press-loads of each trial step were made and set aside for the study.

Figure 1: OSB variables selected for study.

Panel Types / Groups	Target Density (lbs/ft^3)	Surface Resin (% solids)	Core Resin (%)	Surface Wax (% liquid)	Core Wax (% liquid)	Target Thick. (in.)	Press Time (sec.)
Group 1: 34.5 lbs/ft^3	**34.5**	3.0	2.0	1.8	0.6	0.430	153.0
Group 2: 39 lbs/ft^3	**39.0**	3.0	2.0	1.8	0.6	0.430	153.0
Group 3: 42.9 lbs/ft^3	**42.9**	3.0	2.0	1.8	0.6	0.430	153.0
Group 4: Resin	34.5	**4.25**	**4.0**	1.8	0.6	0.430	153.0
Group 5: Top Surface	34.5	3.0	2.0	1.8	0.6	0.430	153.0
Group 6: Core	34.5	3.0	2.0	1.8	0.6	0.430	153.0
Group 7: Bottom Surface	34.5	3.0	2.0	1.8	0.6	0.430	153.0
Group 8: Sanded Top Sfc	34.5	3.0	2.0	1.8	0.6	0.430	153.0
Group 9: Sanded Bottm Sfc	34.5	3.0	2.0	1.8	0.6	0.430	153.0
Group 10: 1-cycle soak	34.5	3.0	2.0	1.8	0.6	0.430	153.0
Group 11: 3-cycle soak	34.5	3.0	2.0	1.8	0.6	0.430	153.0
Group 12: 8-cycle soak	34.5	3.0	2.0	1.8	0.6	0.430	153.0

2.2 Testing at Mill

During the mill trial, the panels were subject to mill quality assurance procedures, both internal and those set by the APA (The Engineered Wood Association). Panels were randomly selected during each phase of the trial, and were graded and structurally tested in accordance with APA and CSA/ASTM D-1037, CSA 0437 and CSA 0325 standards to assure that they met all the requirements to be grade stamped and sold as commercial PRS OSB panels. This aspect was important in assuring that the ranges in which the production variables were set, were within the limits of producing commercially viable panels. After the required storage time in the warehouse for hot-stacking, they were packaged and shipped to Toronto for this study.

2.3 Specimen Preparation

The mill panels from each group were sorted by density, and panels which came closest to matching the target densities of the study (34.5 lbs/ft3, 39.0 lbs/ft3, and 42.9 lbs/ft3) were selected. Later, at the laboratory, the three panel groups of one, three and eight cycle soaking and drying were prepared, again at standard density, resin and wax additions. The panels were first cut into permeance specimen size discs (92 mm diameter), and then submersed in cold water for 24 hours, followed by drying in a laboratory oven at 102^{o}C +/-2^{o}C for 24 hours. The soaking and drying were repeated for the required number of cycles. This moisture cycling method is only to give a hypothetical, worst case scenario, and not intended to simulate real life conditions.

The final variable studied was the individual component layers of OSB. The individual layer specimens (top surface, core and botton surface) were prepared by carefully planing off the other layers, leaving only the layer to be studied.

2.4 Laboratory Testing

A slightly modified form of the commonly used cup test, ASTM E 96-95 (Standard Test Methods for Water Vapor Transmission of Materials) was used to measure the permeance of the OSB specimens (Figure 3). In the standard cup test, the material to be evaluated is sealed as a lid onto a dish or cup, containing either a desiccant (Dry Cup test) or liquid water (Wet Cup test). Next, the whole test assembly is placed into a controlled atmosphere chamber at 50% RH. Periodic weighing of the cup and lid assembly determines the rate of mass gain or loss, and in turn the permeance of the material, but at only two RH gradients, and each spanning a 50% RH range.

The modification to the ASTM cup test method applied in this study, was the use of saturated salt solutions for the control of relative humidity, allowing specimens to be tested through five relative humidity gradient steps, ranging from 2% RH up to 85% RH. It is a property of most salts, that when in the form of a saturated solution within a given temperature range, they create an environment of constant relative humidity above them, unique to that salt. The reason for this test method modification is that OSB, being made of wood, is a hygroscopic material, and as such, it's permeance varries greatly with relative humidity. Therefore, evaluating the permeance of hygroscopic materials across only two relative humidity gradients in accordance to the ASTM Cup Test method is of limited use for the accurate characterization of the material, and for the end goal of using the data for hygrothermal modeling and building design.

In this study, the moisture flux was always maintained in the direction of from the chamber into the cup. Thus, the chamber was always maintained at a higher relative humidity than the cup. Each step of relative humidity is listed in fig. 2, with the first salt listed as the one in the chamber, and the second listed as the one in the cup, and the resultant relative humidities of each below. The average specimen relative humidity is the arithmetic mean of the cup and chamber relative humidities, and is that which would be measured at the midpoint of the specimen. A desiccant consisting of molecular sieves was used in the cup in the first step to attain a relative humidity as close to zero as possible. The same specimens were used throughout the experiment at every relative humidity step.

Fig.2: Salt solutions used and the relative humidities of each.

Salts in Chamber: Salt in Cup:	**$CaCL_2$ - Desiccant**	**$MgNO_3$ - $CaCl_2$**	**$NaNO_2$ – $MgNO_3$**	**NaCl - $NaNO_2$**	**KNO_3 – NaCl**
Chamber RH:	28.00%	50.00%	60.00%	70.00%	85.00%
Cup RH:	2.00%	29.00%	53.00%	64.40%	75.00%
Avg Specimen RH (%)	**15.00%**	**39.50%**	**56.50%**	**67.20%**	**80.00%**

The constant humidity and temperature chamber consisted of a plexiglass box, with dishes of saturated salt solutions for relative humidity control and two circulating fans (Figure 4). The chamber was in turn placed in a guard room within a temperature controlled room set at 21^{o}C. The temperature inside the chamber was controlled by means of small sheilded lightbulbs, activated by a control program, which maintained the temperature of the chamber at 25°C (+/- 0.5°C). RH was monitored with a Vaisala RH meter and temperature probe, and verified periodically by means of a sling psychrometer.

Fig. 3: Test cup and specimen.

Fig. 4: Temp and RH chamber.

3 RESULTS AND DISCUSSION

Permeance specimens exhibited a very steady rate of mass gain over the entire test period for each relative humidity step. Each series shown is the average of the results from five specimens (Figure 5).

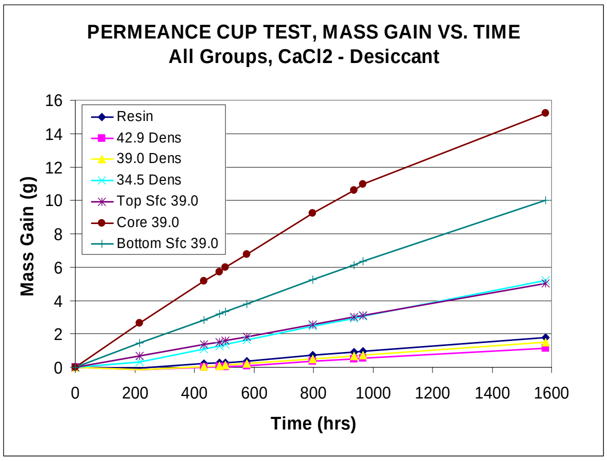

Fig. 5: Mass Gain of Specimens over 66 days, at first RH range (2% - 28%).

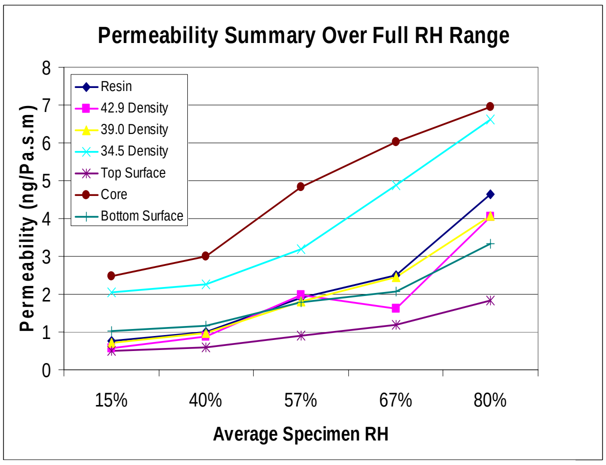

Fig. 6: Permeabilities of Various Groups over Full RH Range.

Each five specimen average plot will yield one permeability value at that given relative humidity and relative humidity gradient. For the purposes of comparison, the mass data has been converted to permeability and a series of plots over the entire relative humidity range as shown in figure 6.

As would be expected with a hygroscopic material, the permeability in each group increases with relative humidity. This behaviour of hygroscopic materials can be explained by the various moisture transport mechanisms involved (J. Arfvidsson, 1989), but will not be dealt with in this paper. As the relative humidity increases, permeability increased by approxmately three-times in the core layer group, and up to a seven times in the 42.9 lbs/ft^3 (689 kg/m^3) "higher" density group. These results underscore the need to know the permeance of hygroscopic materials such as OSB over the entire relative humidity range.

Another, perhaps more important finding is the difference in the permeabilities among the various series. Where only density was varied, it was found that the lowest density group, 34.5 lbs/ft^3 (554 kg/m^3), shows the highest permeability. The highest density group (42.9 lbs/ft^3, 689 kg/m^3) had the lowest permeability and the mid density group, (39.0 lbs/ft^3, 626 kg/m^3) was in between. As intuitively expected, the relationship between density and permeability is inverse. The higher the density of a given material, the lower the permeability. This is due to a reduction in the number of voids or free paths not blocked by material through which water vapour can diffuse. The relationship can more easily be seen by plotting the densities of individual specimens against permeability at each relative humidity range (figure 7). The relationship between permeability and density can best be described by a logarithmic function for each RH step, as shown in Figure 7.

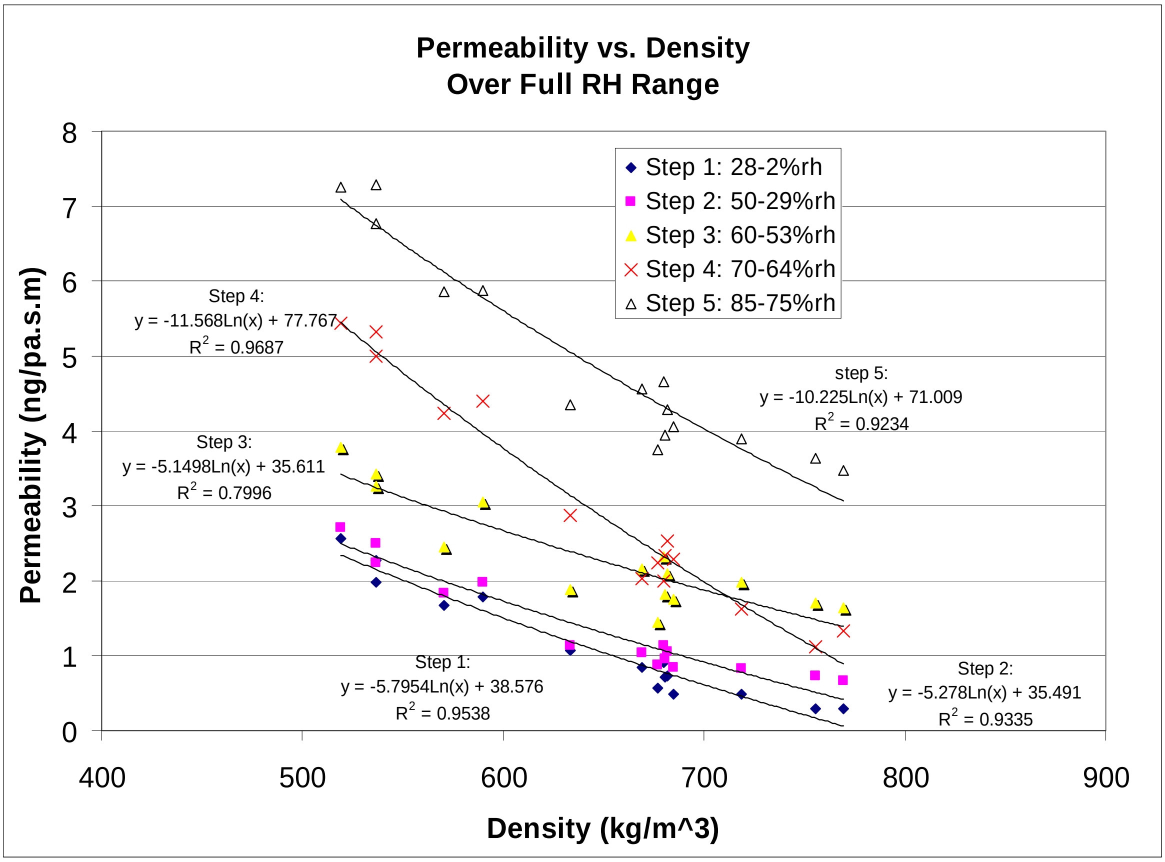

Fig.7: Permeability vs. Density for Various Relative Humidity Ranges.

An examination of Figure 6, again reveals that each component layer has a very different permeability. The experimental results clearly show that the core layer has the highest permeability and the top surface layer has the lowest permeability of all the series, throughout the relative humidity range. Thus, OSB is not a uniform homogenious material; OSB should be seen as being composed of three distinct individual component layers. Each layer has very different properties that result from the manufacturing process. First, the resin and wax addidion levels are not the same for all layers. Surface layers typically have 50% more resin and 200% more wax than the core layer. Second, there is a large variation in density throughout the thickness of OSB. Surface layers are significantly more dense than the core. This is because of the heat transfer process during pressing, resulting in the outer surfaces plasticising and densifying to a higher degree than the core at the center of the panel. Third, there is also a difference in the very outer surfaces as a result of how the panel is pressed. The very top surface has a glassy smooth finish since it is in direct contact with the hot metal platen of the press. The bottom surface, with the exception of panels made on a continuous press, will have a rough, textured surface from having been pressed on a caul screen used with a multi-daylight opening type press. The other possible variations in moisture performance properties may be due to the migration of resin, wax, gases and moisture during pressing.

The final series in Figure 5 has been called "resin". The resin-rich samples have been made by raising the resin addition rate for both the surface and core layers to the upper end of the commercially feasible limit. These high-resin specimens showed little difference in permeability from the 39.0 lbs/ft^3 (626 kg/m^3) density control group, indicating that the resin addition level has little influence on permeability of OSB as compared to density.

The impact of cyclic wetting and drying, as well as of sanding on permeability are illustrated in Figure 8. These tests were carried out at the middle relative humidity range of 49% - 29% rh. This series of tests was conducted using standard density (39.0 lbs/ft^3, 626 kg/m^3) and resin addition levels (3.0% surface, 2.0% core), and can be compared against the control (standard density and resin content, non-cycled 7/16"PRS). Cyclic wetting and drying clearly has a large effect on permeability. Following one cycle of wetting and drying, permeability more than doubled. Subsequent cycles had a diminished effect.

Sanding on the otherhand, had a far lesser effect on permeability. However, recalling the variation in permeability between the various component layers illustrated in figure 6, one would expect that a removal of the top or bottom surface material should change the overall permeability. The degree of sanding or the amount of surface material removed may not have been sufficient in this preliminary investigation to have shown a significant impact, and will have to be further studied.

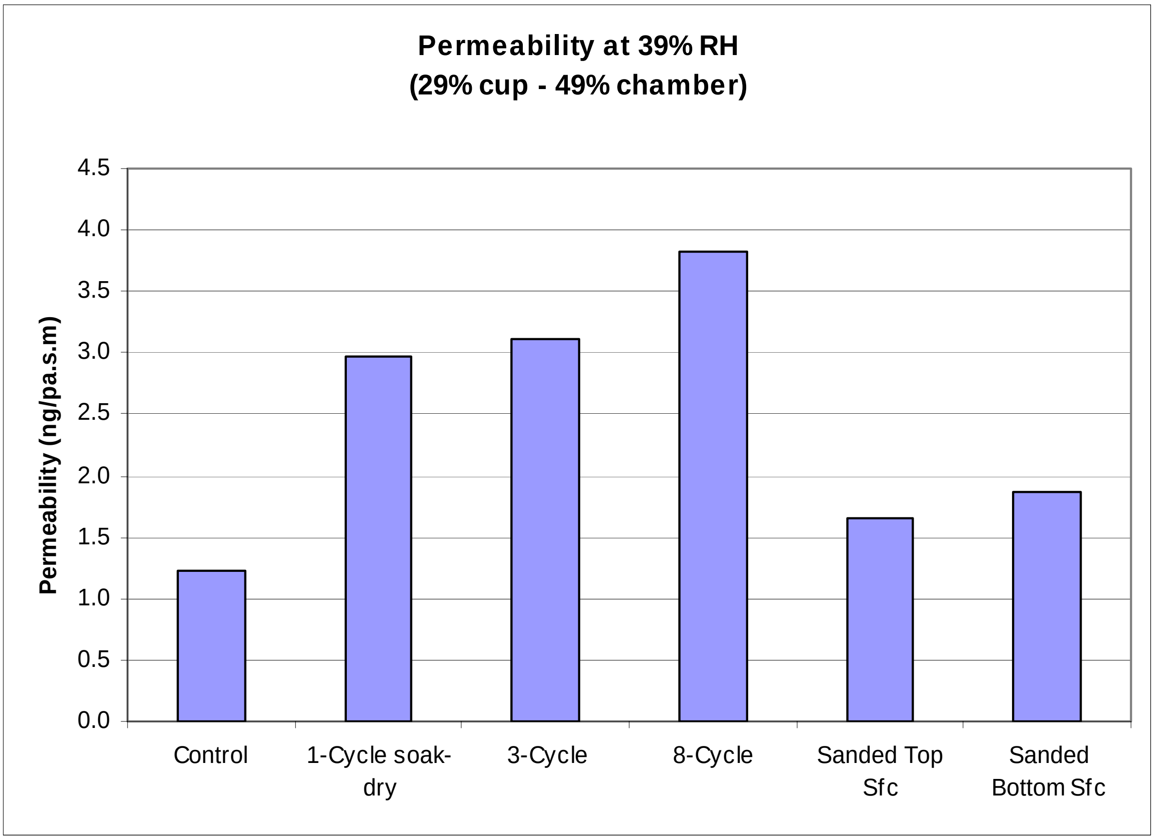

Figure 8: Effect of cyclic soaking and drying, and sanding on permeability.

4 CONCLUSION

The permeability of OSB can vary several fold as a result of variation in the manufacturing parameters at the mill. Further, it varies significantly when subjected to cycles of wetting and drying. This strongly suggests that in addition to virgin material moisture properties, those which result from wetting and drying should be considered in design and analysis. A simple factor such as whether or not the OSB has been sanded or not, may alter the permeability slightly, depending on the degree of sanding. When wall, roof or floor systems are designed with OSB, these variations in permeability may have an impact on the overall moisture performance of the wall system, and ultimately on whether or not mould, mildew or rot will develop under adverse service conditions. Ultimately, both the designer and the OSB manufacturer can take advantage of these variations in permeability in order to optimize building systems for occupant health, efficiency and durability

5 ACKNOWLEDGMENTS

The author would like to acknowledge the generous financial support of this research and guidance throughout the project by Trow Associates Inc., of Brampton, Ontario, and by CRESTech through their Cooperative Research Award.

6 REFERENCES

APA- The Engineered Wood Association. 2003. *Performance Standards and Policies for Structural Use Panels.* APA PRP-108. Tacoma, WA: APA- The Engineered Wood Association.

Arfvidsson, J. 1989. *Computer model for two-dimensional moisture transport. Manual for JAM-2.* Department of Building Technology, Lund University, Lund.

Straube, J.F. 1998. *Moisture Control and Enclosure Wall Systems.* Ph.D. Thesis, Civil Engineering Department, University of Waterloo.