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SELECTION TOOL FOR WATER-RESISTIVE BARRIERS WITH SUITABLE VAPOUR PERMEABILITY

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ABSTRACT

The variety of water-resistive barriers (WRB) has changed significantly over the past several decades. Commonly referred to as `breathable' housewraps, advances in the application of polymers have brought new polymeric water-resistive barriers with a wide range of vapour permeability to market. However, a significant information gap has led to uncertainty among design professionals, and in the construction industry at large, regarding the in-service performance of various WRB products and the selection of the optimum vapour permeability under specific conditions.

This paper describes a research project that evaluates the influence of various water-resistive barriers with the hygrothermal performance of different wall assemblies. The model variables included: Variations in boundary conditions/climatic conditions (seven climatic locations), cladding type (brick, adhered manufactured stone veneer, cement-board, three-coat stucco) and the type of WRB (low versus high vapour permeability) deployed.

In the first phase, the water-vapour permeability of different water-resistive barriers was measured. Next, a sub-system test was carried out. This test was designed to simulate performance of a small component of a wall system under controlled conditions in order to predict the performance of large-scale assemblies, and to support the performance simulation tool findings. A number of parameters were varied including substrate, cladding and climatic locations. In the next phase, simulations were carried out with a hygrothermal model (WUFI PRO 5.1). The sheathing moisture content, temperature and relative humidity were plotted versus time and presented as an index of moisture performance. In the last phase, the results were incorporated into a software selection tool, allowing an architect to select a specific climate zone, cladding type, water-resistive barrier with a particular perm rating, and wall orientation. Finally results were presented as a function of moisture performance index (mold index).

INTRODUCTION

The primary function of a water-resistive barrier (WRB) in a building enclosure system is to serve as a second line of defense and to shed water that penetrates the cladding. Even though the building enclosure may be designed properly by design professionals, experience shows that defects created during the construction process or those occurring during the service life of the structure may allow water to enter the wall assembly. Hence, for a wall assembly to function well, it should be designed to permit drainage on the surface of the water-resistive barrier. This latter feature is particularly important for wood-frame construction in order to dry any excess moisture. Therefore, the water-resistive barrier should be vapour permeable in order to allow for outward diffusion of water vapour. The moisture balance of the building material adjacent to the water-resistive barrier will be strongly affected by the water vapour flow caused by thermal drive, which may vary depending on the moisture content and temperature of outdoor air. The moisture balance will also be dependent upon solar radiation. A reverse thermal gradient may cause inward vapour diffusion into the wall cavity. For this reason water-resistive barriers need to be evaluated in regards to their effect on the performance of a wall assembly (Jablonka, 2011).

Different types of water-resistive barriers may be incorporated into the wall assembly. Depending on the climatic conditions and the type of sheathing and cladding material used, different WRB's will have different effects on wall performance and durability. The available variety and characteristics of such membrane products have changed significantly over the past several decades. Advances in the application of polymers brought a large variety of "breathable housewraps" with a wide range of vapour permeability to the market. However, the large variety of performance characteristics has resulted in uncertainty among design professionals, and the construction industry at large, regarding the in-service performance of various types of water-resistive barriers and the selection of the optimum vapour permeability under specific conditions. This paper describes a research project that evaluates the impact of various water-resistive barriers with a large range of vapour permeability on the hygrothermal performance of different wall assemblies - information vitally important for proper product selection. For the convenience of designers the results of this research project have been summarized in a software selection tool.

OBJECTIVE

The objective of this research project was to understand the performance of different water-resistive barriers with various vapour permeabilities in different climates and cladding applications in building wall assemblies. The sensitivity to different types of water ingress (location in the wall assembly) was examined as a function of water-resistive barrier and climate.

SCOPE

Variations in boundary conditions included climatic conditions (seven climatic locations), cladding type (brick, adhered manufactured stone veneer, cement-board, three-coat stucco) and type of WRB (low versus high vapour permeability) deployed.

The research approach was structured into several phases. In the first phase the water vapour permeability of different water-resistive barriers were determined as per ASTM E96-00. Subsequently a sub-assembly laboratory test was designed to simulate performance of a small component of a wall system during operation under controlled conditions to predict the performance of large-scale assemblies, and to validate the performance simulation tool. A variation of the hygrothermal loads was performed to allow gapping between perfectly built wall assemblies and walls with realistic imperfections (workmanship issues). A number of parameters were varied to understand the sensitivity of the results to the different types of substrate, cladding and climatic locations. In the next phase simulations were carried out with a hygrothermal computer model (WUFI 5, Karagiozis et al [2001]). The sheathing moisture content, temperature and relative humidities were plotted against time for comparison and analysis, and presented as an index of moisture performance. In the final phase the results were embedded into a software selection tool, allowing an architect to select a specific climate zone, cladding type, water-resistive barrier with a particular perm rating, and wall orientation. Results are being presented as a function of moisture performance index (mold index).

WATER VAPOUR PERMEANCE TESTING

Material property and sub-assembly tests were performed to support and strengthen the computer simulations. The table below shows a summary of the water-resistive barriers that were tested and their dry cup and wet cup vapour permeance values determined using ASTM E96-00 Method A and Method B (Straube et al., 2010). The test dishes were sealed with aluminum tape to ensure that the only vapour movement observed was through the test specimen. The standard requires a minimum sample size of 3000 mm2. Samples of 16,200 mm2 were used to ensure that the test results are not influenced by local variations in vapour permeance of the sample. The temperature was controlled to 23C as specified for Method B. The relative humidity was kept constant at 50%. Further details of this part of the laboratory testing is described in Straube et al., 2010.

	Method A	Method B
Water-resistive barrier	Dry Cup	Wet Cup
	[ng/Pa m^2 s]	[ng/Pa m^2 s]
WRB A	12,284 (214 perms)	13,812 (241 perms)
WRB B	804 (14 perms)	1,597 (28 perms)
WRB C	3,444 (60 perms)	3,737 (65 perms)

TABLE 1: SUMMARY OF VAPOUR PERMEANCE AS PER ASTM E96 (DRY CUP VERSUS WET CUP METHOD)

The wet cup (Method B) testing did result in higher average permeance values than the dry cup (Method A) testing, as anticipated. The greatest increase in vapour permeance occurred with the WRB B water-resistive barrier which nearly doubled in vapour permeance between the dry cup and wet cup tests. The wet cup vapour permeance test is more appropriate for determining the drying performance of walls as the cladding in many climates is more often between 50 and 100% relative humidity (wet cup conditions), than between 0 and 50% relative humidity.

Sub-assembly testing

Testing the vapour permeance according to ASTM E96 demonstrates how the water-resistive barrier performs as an individual material, but it is also important to understand how the water-resistive barrier performs in combination with OSB or exterior gypsum sheathing, which more closely simulates a wall assembly. A sub-assembly laboratory study was undertaken to more clearly understand the drying ability of water-resistive barriers in combination with OSB or exterior grade gypsum sheathing. The sub-system testing was designed to simulate performance of a small component of a wall system during operation under controlled conditions to predict the performance of large-scale assemblies, and to validate the performance simulation model.

Two different types of polymeric, vapour permeable water-resistive barriers and #15 asphalt impregnated building paper were tested in the sub-assembly test. Twenty-seven sub-assembly test samples were made using three different water-resistive barriers installed on either OSB or exterior grade gypsum sheathing as shown in the testing matrix in Table 2 below. The differences between interior and exterior wetting are shown in Figure 1.

	OSB - interior wetting	OSB - exterior wetting	Gypsum sheathing - interior wetting	Gypsum sheathing - exterior wetting
WRB A	4	1	3	1
WRB B	4	1	3	1
Building Paper	4	1	3	1

TABLE 2: TESTING MATRIX – NUMBER OF SUB-ASSEMBLY SAMPLES OF EACH CONSTRUCTION

Square samples measuring 330 x 330 mm (13" x13") were cut from sheets of OSB and exterior grade gypsum sheathing. The edges of the samples were wrapped with foil tape to create a 305 x 305 mm (12" x12") active test area. Four layers of moisture storage media were installed between the sheathing and the water-resistive barrier to simulate exterior wetting, or installed on the opposite side of the sheathing from the water-resistive barrier, to simulate wetting on the interior, in the stud cavity as shown in the schematic in Figure 1. A 0.125" ID tube was installed to provide water to the moisture storage media.

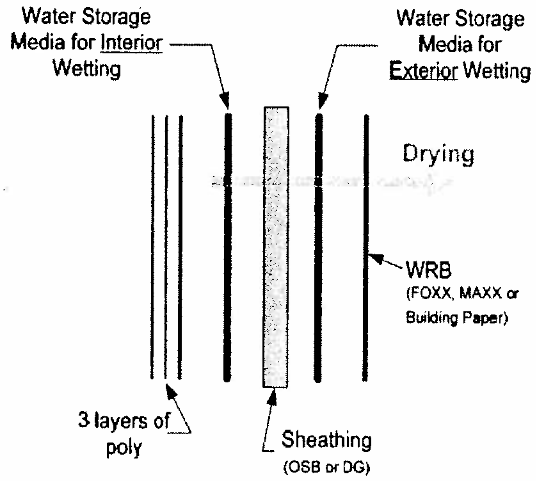


FIGURE 1: SUBASSEMBLY TESTING SAMPLE SCHEMATIC

Editor's Note: In the interests of brevity, details of the experimental method and detailed results have been omitted but is available from the authors.

Summary Sub-Assembly Testing

Table 3 shows a summary of the sub-assembly testing results and the effective sample vapour permeances.

	Mass loss [g/day]	Effective Sample Permeance US Perms	Effective Sample Permeance [ng/Pa s m^2]
WRB A			
interior wetting on OSB	1.4	2.2	126
exterior wetting on OSB	40.6	89	5108
interior wetting on gypsum sheathing	37.1	56.4	3240
exterior wetting on gypsum sheathing	52.2	92.6	5317
WRB B			
interior wetting on OSB	1.1	1.7	96
exterior wetting on OSB	16.1	24.8	1423
interior wetting on gypsum sheathing	15	23.1	1327
exterior wetting on gypsum sheathing	16.1	24.8	1423
Building paper			
interior wetting on OSB	0.5	0.8	45
exterior wetting on OSB	12	18.6	1070
interior wetting on gypsum sheathing	9.3	13.8	794
exterior wetting on gypsum sheathing	10.7	15.8	908

TABLE 3: SUMMARY OF SUB-ASSEMBLY TEST RESULTS AND EFFECTIVE SAMPLE PERMEANCES

The following conclusions can be drawn from Table 3:

If water were to enter on the interior of the OSB, it would dry twice as quickly with WRB B as with building paper, and three times as quickly with WRB A as with building paper, although the rate of drying is quite slow since the permeance in all cases is controlled by the absorptivity and vapour permeance of the OSB.

If water were to enter on the interior of exterior grade gypsum sheathing, it would dry 1.5 times as quickly with WRB B instead of building paper, and would dry 2.5 times as quickly with WRB A as with building paper.

If water were on the exterior of the OSB sheathing between the sheathing and the water-resistive barrier, it would dry 1.3 times more quickly with WRB B than with building paper, and 3.3 times more quickly with WRB A than with building paper.

If water were on the exterior of the exterior grade gypsum sheathing between the sheathing and the water-resistive barrier, the water would dry 1.5 times more quickly with WRB B than with building paper, and almost 5 times more quickly with WRB A than with building paper.

These tests were conducted without a temperature gradient across the sub-assembly sample. Using a temperature gradient would increase the vapour pressure equally for all samples, and should increase the drying rate equally.

In all cases, the effective permeance of the samples with WRB A had a higher effective vapour permeance than the similar tests with WRB B, and the WRB B samples had a higher effective vapour permeance than similar tests with building paper.

In all cases of interior wetting of the OSB, with no temperature gradient, the drying was very slow and controlled by the OSB sheathing. The type of water-resistive barrier did not significantly affect the drying rate of the OSB.

Comparing the exterior wetting of OSB and exterior grade gypsum sheathing with WRB B, the resulting effective vapour permeance is very close to the ASTM E96 Wet Cup value of 28 perms (1597 ng/Pa·s·m2) determined in phase one of this study. Exterior wetting beneath the WRB A resulted in effective vapour permeances of approximately 1/3 of the ASTM E96 Wet Cup value. WRB A has a high vapour permeance and may not have been maintaining 100% RH between the sheathing and the water-resistive barrier.

SIMULATIONS WITH HYGROTHERMAL MODEL

The thermal and hygric behaviour of building enclosure components are closely interrelated and therefore have to be investigated together. Permanently increased moisture content in a building enclosure component may result in moisture damages and mold growth. Increased moisture content in building components favours heat losses, and thermal conditions affect moisture transport.

To investigate how the water-vapour permeability of a WRB affects the performance of a building enclosure under various climatic conditions and in conjunction with different sheathing materials and cladding materials, hygrothermal simulations were performed with WUFI 5. This software model allows the one-dimensional investigation of the hygrothermal performance of building components including effects like built in moisture, driving rain, solar radiation, long-wave emission, capillary transport and summer condensation (Künzel and Karagiozis, ASTM Manual 40).

The following climatic locations were chosen for the hygrothermal simulations (climate zone references according to the International Energy Conservation Code zoning):

- Miami, FL (Climate Zone 1)
- New Orleans, LA (Climate Zone 2)
- Atlanta, GA (Climate Zone 3)
- San Francisco, CA (Climate Zone 3)
- Baltimore, Maryland (Climate Zone 4)
- Portland, OR (Climate Zone 4)
- Seattle, WA (Climate Zone 4)
- Chicago, IL (Climate Zone 5)
- Minneapolis, Minnesota (Climate Zone 6)
- Fairbanks, Alaska (Climate Zone 7)

Two different exterior sheathing materials were considered for the hygrothermal simulations: Oriented strand board (OSB) and exterior grade gypsum board.

The following cladding materials were investigated:

- Brick
- Adhered manufactured stone veneer
- Cementitious stucco
- Cementitious siding

Six different water-resistive barrier scenarios were investigated:

- Building paper
- Low-perm membrane (1 perm)
- WRB A
- WRB B
- Combination of WRB C with ventilated rainscreen membrane (Product D)

In regards to the inner wall construction IRC code requirements were deployed, e.g. a vapour retarder on the warm side of the insulation was only used where required by building code. The building paper and the low-perm membrane case were used for comparison. The last case (combination of WRB C with Ventilated Rainscreen D) comprised a highly water-vapour permeable water-resistive barrier with an impermeable, three-dimensional rainscreen HDPE membrane (dimple sheet) which was ventilated on the front and backside. This scenario was chosen to investigate the beneficial effect of combining drying potential for any moisture within the wall cavity (via vapour diffusion through the permeable water-resistive barrier into the ventilated cavity outside) and an impermeable layer outboard of the ventilated airspace in order to prevent inward moisture movement from absorptive cladding due to solar drive. The beneficial effect of a ventilated vapour impermeable rainscreen product has been evaluated and discussed in detail by Straube et al (2009), and by Jablonka, Karagiozis and Straube (2010).

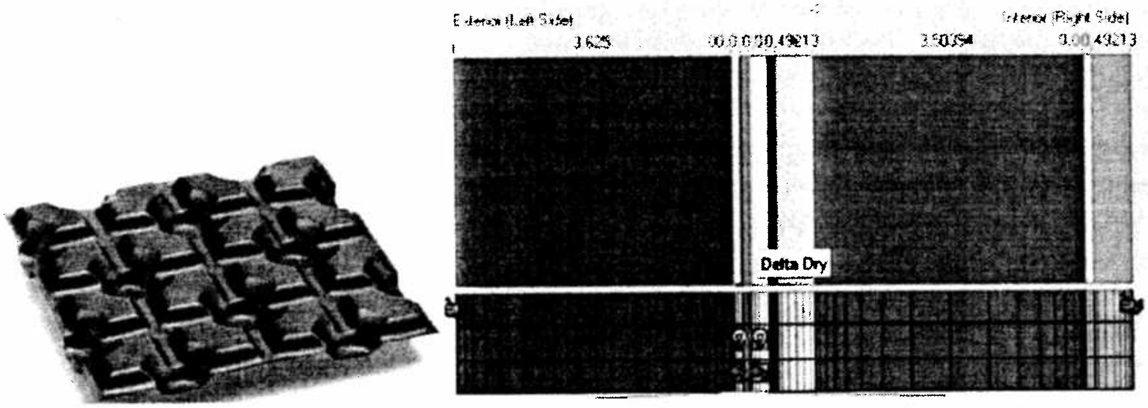


FIGURE 2: VENTILATED RAINSCREEN D, CONFIGURATION WITHIN WALL ASSEMBLY

The key properties for water-resistive barriers that were measured earlier on in the project were used in the analysis. The heat (conduction) and moisture transport (vapour diffusion and capillary conduction) were deployed in the simulations in one-hour time steps. Hourly indoor and outdoor climatic conditions as per ASHRAE Standard 160-2009 were used and the assumption was applied that 1% of the precipitation water that hits the cladding would leak through or enter behind the cladding. Additional analysis was performed where 0.75% water penetration took place between the water-resistive barrier and sheathing board, and 0.5% of water penetration between the sheathing board and insulation were also included into the parametric. Analysis was performed in one-hour steps for a two-year period for the selected wall enclosure systems. The interior conditions were calculated from the exterior weather file used in the hygrothermal simulation by applying the intermediate method from ASHRAE Standard 160-2009.

Material property inputs were taken from the WUFI North American database with the exception of the adhered manufactured stone veneer where measured data was used. The WUFI database for North America includes the data from NRC (Kumaran, 2001).

Connection of model and sub-system testing:

As with all modeling activities, it is important to capture the sub-system effects. When these sub- system effects are properly captured the accuracy of the predictions are expected to be higher. Prior to the execution of the hygrothermal analysis, the basic properties of the water-resistive barriers were measured (Straube et al., 2010). Then a series of sub-system tests were performed as described in the previous sections. The 1-D hygrothermal model (WUFI 5) was used to validate the drying performance of the various experimental results. Good agreement was found between the model predictions and the measured drying rates for the various laboratory sub-systems tested. The validation provided the necessary confidence in the results to engage in the comprehensive hygrothermal parametric analysis.

For the simulation cases that included the Ventilated Rainscreen D, two air cavities were included into the WUFI 5 model. The air exchange rates within the two air cavities were calculated based on the procedure developed within ASHRAE TRP 1091 (Burnett, Straube and Karagiozis, 2004) which was also detailed in Journal of ASTM International by Karagiozis and Kuenzel (2007). The flow equations with the entrance and exit pressure drops were used, as well as the flow resistance along the length of the ventilated rainscreen membrane (Product D). The effect of stack pressures, wind pressures and moisture concentration gradients are combined to produce a net force for driving air flow in each of the two cavities that the Ventilated Rainscreen D creates. These mass flows were converted into cavity air changes per hour (see Karagiozis and Kuenzel, 2009), and allowed to calculate the dynamic impact of exterior and interior boundary conditions. Input files were created for the hygrothermal analysis using WUFI. The WUFI model has been extensively validated for many different cladding cavity configurations and has shown excellent agreement with measured field data.

Three surfaces were selected as the critical layers for detailed analysis: The exterior surface of the exterior sheathing board (P1), the interior surface of the exterior sheathing board (P2), and the interior side of the insulation layer in the wall cavity (P3). Selection points both on the interior and exterior side of the wall cavity ensured that the climatic effects were captured in the performance analysis.

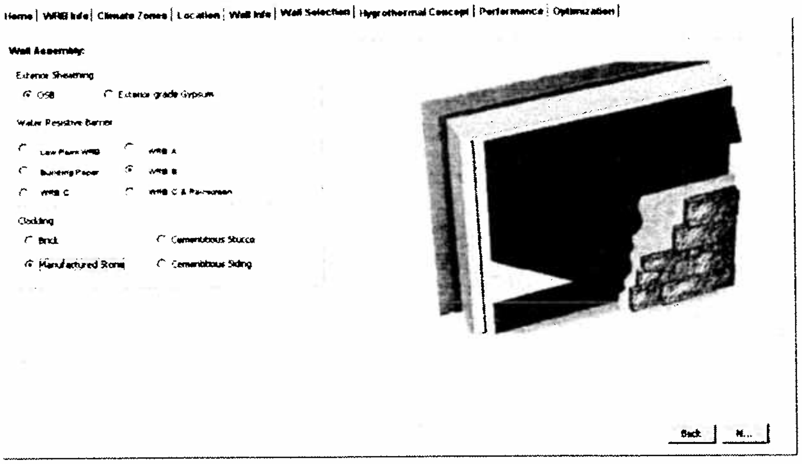
The maximum mold growth index for each point was investigated. The mold growth index, as described in depth by Viitanen (Viitanen, 2010), makes it possible to analyse the critical conditions needed for the start of mold growth and to measure the progress of mold growth.

First, all points were checked against a reference value. The average of the maximum mold growth index of these three points was calculated, and this value was then used as a performance indicator for ranking. The lowest value has the highest ranking, representing the best wall performance in regards to moisture management.

SOFTWARE SELECTION TOOL

Wall assemblies with various cladding types in different climates demand the proper selection of water-resistive barriers for optimal performance. The results of the measurements and hygrothermal simulations with WUFI 5 described in this paper were summarized in a software tool that helps the designer simply and effortlessly choose the most suitable water-resistive barrier for a particular wall assembly configuration. Furthermore, it provides a design recommendation for optimal wall performance based on a performance ranking by water-resistive barrier type. A damage function is used for guidance to provide insight on performance of these different water-resistive barriers.

The software tool allows for a step-by-step selection process as shown in Figure 3.



Wall Assembly:

Exterior Sheathing

● OSB ○ Exterior grade Gypsum

Water Resistive Barrier

○ Low Perm WRB ○ WRB A

○ Building Paper ● WRB B

○ WRB C ○ WRB C & Rainscreen

Cladding

○ Brick ○ Cementitious Stucco

● Manufactured Stone ○ Cementitious Siding

FIGURE 3: SOFTWARE TOOL FOR SIMPLE SELECTION OF MOST SUITABLE WATER-RESISTIVE BARRIER

The user gets prompted to select the location from a list or map. A total number of 13 locations are available for selection by the user. These locations were carefully selected in order to cover all climatic zones of the US; the user would choose the location that would be closest to the location of interest within the same climate zone. In the next step the user gets prompted to choose the type of exterior sheathing (OSB or exterior grade gypsum board). Furthermore the user can choose from one of six options for water-resistive barrier with a wide range of water vapour permeability. The last step in the selection process allows the user to decide between four different cladding options: Brick, adhered manufactured stone veneer, cementitious stucco and cementitious cladding.

The performance results for the selected wall assembly for that particular climatic location are then presented in a summary screen as shown in Figure 4.

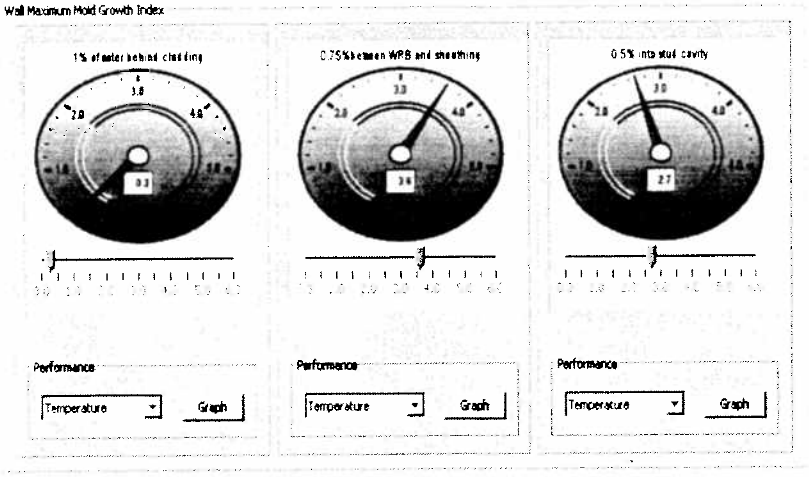


FIGURE 4: SUMMARY SCREEN FOR WALL PERFORMANCE UNDER SELECTED CONDITIONS

The summary screen provides three gauges with a range from 1 to 6. In this way the designer is provided with a simple overview of how well a particular wall assembly would function under the chosen conditions.

The first gauge on the left provides the maximum mold growth index for the assumed best case scenario that 1% of the precipitation water that hits the façade will leak through the cladding but remain on the outside of the water-resistive barrier. The second gauge in the middle provides the maximum mold growth index for the assumed case that 0.75% of that water enters between the water- resistive barrier and the sheathing board. The third gauge on the right presents the maximum mold growth index for the assumed case that 0.5% of that water enters into the wall cavity (backside of the exterior sheathing material). By presenting all three gauges in one view the designer gets a quick impression of how well a wall assembly would perform under optimal versus suboptimal (more realistic) conditions (e.g. missing flashing, penetrations in water-resistive barrier, etc.).

If desired, the designer can pull up detailed graphs for temperature, relative humidity and moisture content for each of the three scenarios. The graph in Figure 5 shows a typical example for temperatures measured in the three sensor locations P1, P2 and P3 for the simulated 2-year period.

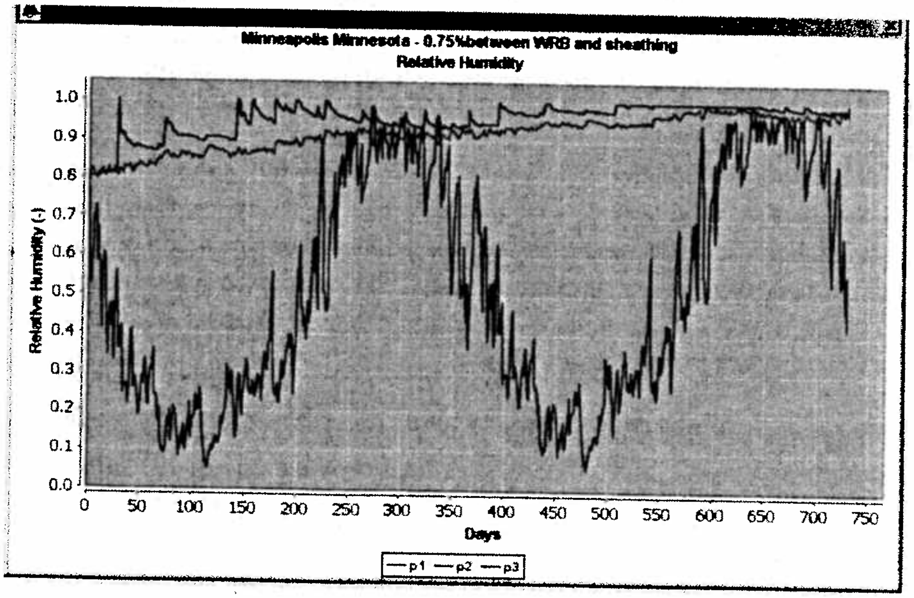
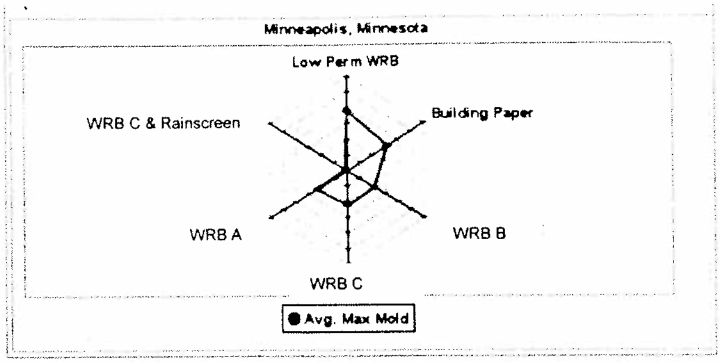


FIGURE 5: RELATIVE HUMIDITY PREDICTED OVER 2 YEARS IN LOCATIONS P1, P2 AND P3 FOR SELECTED CONDITIONS

For simplicity a performance overview is provided to the designer as shown in Figure 6.



Recommendation for optimum wall performance:

1. WRB C & Rainscreen D	65 US perms
2. WRB B	28 US perms
3. WRB C	65 US perms
4. WRB A	241 US perms
5. Building Paper	0.5 to 40 US perms
6. Low Perm WRB	< 1 US perms

FIGURE 6: PERFORMANCE OVERVIEW AND PERFORMANCE BASED RANKING FOR VARIOUS WRB OPTIONS: SMALLER VALUES (CENTER OF DIAGRAM) INDICATE BETTER PERFORMANCE

The performance overview chart shows the six different of water-resistive barrier scenarios that were analyzed. Lowest mold growth index (optimum hygrothermal performance) is achieved in the center of the diagram. The further the red line moves to the outside of the diagram the more mold growth has to be expected under the chosen circumstances. The list below the diagram shown in Figure 6 provides a performance ranking of the different water-resistive barrier scenarios for that particular climate zone and the chosen sheathing board and cladding type.

It is apparent that the vapour permeability of the water-resistive barrier has an influence on the average mold growth index, as it affects the drying of interior moisture via diffusion.

Figure 7 and Figure 8 show the average mold growth index for Chicago for adhered manufactured stone veneer and cementitious siding with OSB as exterior sheathing material.

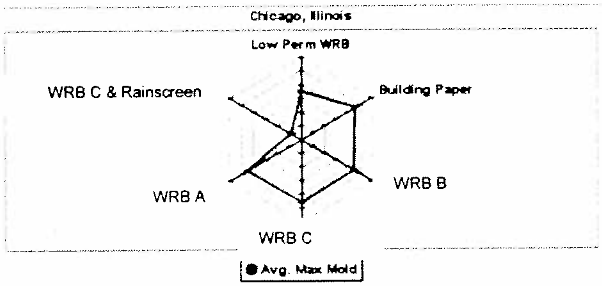


FIGURE 7: AV. MOLD GROWTH INDEX CHICAGO, CHICAGO, ADHERED MANUFACTURED STONE VENEER, OSB AS EXTERIOR SHEATHING

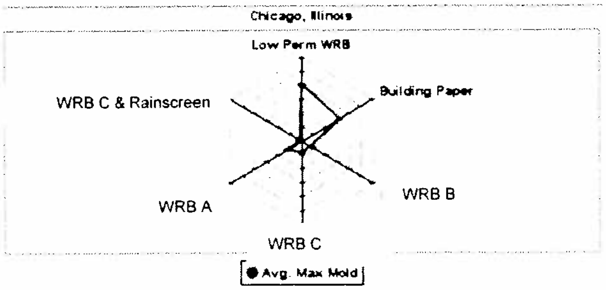
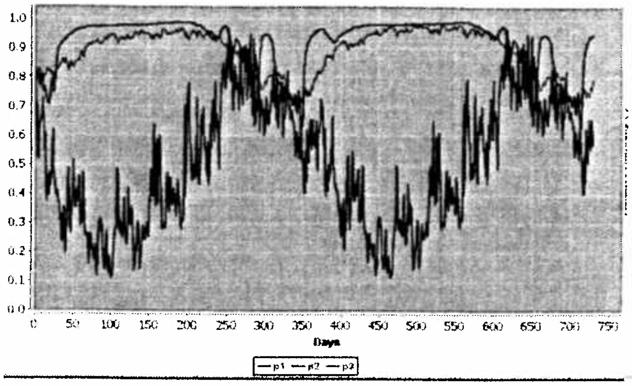


FIGURE 8: AV. MOLD GROWTH INDEX CEMENTITIOUS SIDING, OSB AS EXTERIOR SHEATHING

Figure 9 and Figure 10 show the relative humidity in the three different sensor locations for the same location and cladding materials (1% of precipitation leaked behind cladding).



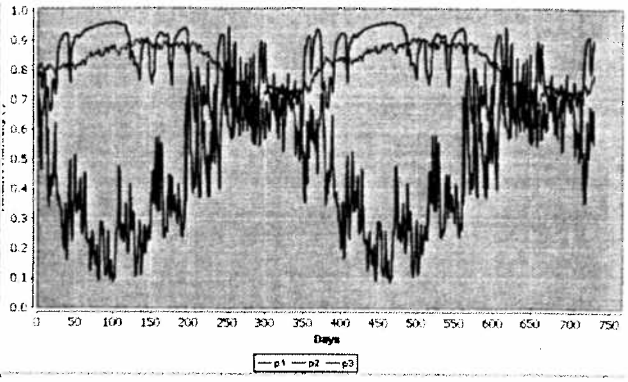
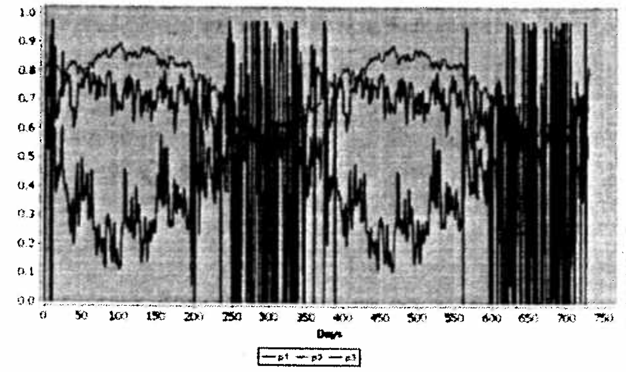


FIGURE 9: RELATIVE HUMIDITY CHICAGO, MANUFACTURED STONE VENEER, *OSB AND WRB C (65 US PERMS)*

FIGURE 10: RELATIVE HUMIDITY CHICAGO, ADHEREDCEMENTITIOUS SIDING, *OSB AND WRB C (65 US PERMS)*

Figure 9 shows that in the Chicago climate the use of a highly vapour permeable water-resistive barrier used behind adhered manufactured stone veneer would lead to elevated levels of relative humidity for long time periods per year (between 90% and 100% RH). The same water-resistive barrier used behind cementitious siding would lead to significantly lower RH values for most of the year (between 70% and 90%). The elevated levels can be explained with solar moisture drive from highly absorptive claddings into the wall cavity. A highly vapour-permeable membrane would allow moisture from the inside of the cavity to easily diffuse to the outside, but in case of reverse vapour pressure differential moisture can also easily diffuse inwards and elevate the moisture levels inside the wall assembly.

The reverse moisture flow can be prevented by using a ventilated, vapour impermeable rainscreen outboard of a highly vapour permeable water-resistive barrier as shown in Figures 11 and 12 (1% of precipitation leaked behind cladding).



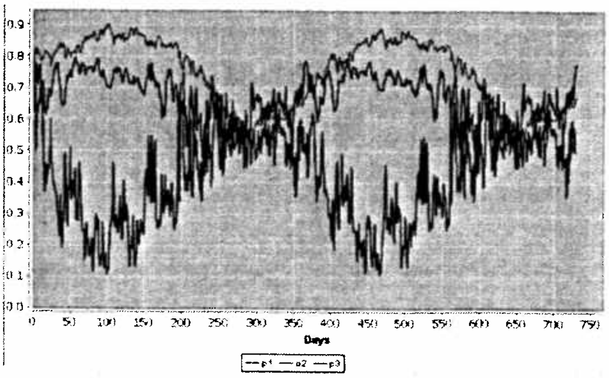


FIGURE 11: RELATIVE HUMIDITY CHICAGO, CHICAGO, ADHERED MANUFACTURED STONE VENEER, OSB AND WRB C (65 PERMS) WITH RAINSCREEN WITH RAINSCREEN

FIGURE 12: RELATIVE HUMIDITY CEMENTITIOUS SIDING, OSB AND WRB C (65 PERMS)

The graphs show that by utilizing a highly vapour permeable water-resistive barrier in conjunction with an impermeable rainscreen product on the outside the relative humidity levels drop noticeably.

Similar results can be seen for other climate zones. Optimum wall performance in any climate zone can generally be achieved by combining a highly vapour permeable water-resistive barrier with an impermeable, ventilated rainscreen material. This combination allows for quick drying of moisture from within the wall assembly to the outside, while moisture from the outside (i.e. stored in absorptive cladding material like adhered manufactured veneer) cannot migrate inward.

CONCLUSIONS

This paper evaluates the impact of various water-resistive barriers with a large range of vapour permeability on the hygrothermal performance of different wall assemblies. A simple-to-use tool has been developed after it was validated with laboratory results.

The results from this tool enable designers to select products with the most suitable vapour permeability for a particular geographical location under specific construction conditions. Variations in boundary conditions included climatic conditions (from seven climatic zones), cladding type (three-coat stucco, manufactured stone, cement board, brick) and type of water-resistive barrier (low versus high vapour permeability) deployed. The results for the performance of the wall systems are presented in form of a mold index. The approach presented includes three possible wetting locations and examines the best drying potential as a function of a range of vapour permeability of the water- resistive barriers.

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