RESEARCH REPORT

Drainage and Retention of Water by Cladding Systems

Part 1– Experimental Approach and Plan

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DRAINAGE AND RETENTION OF WATER BY CLADDING SYSTEMS

Part 1 - Experimental Approach and Plan

Presented to

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30 March, 2007

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SUMMARY

Reporting on the findings of this project has been compartmentalized into a series of “Parts”, this report being the first in the series. Because of the considerable detail involved in reporting on the many wall variants that have been included, it was considered more manageable for the reader to face each segment of the work separately. The final report in the series will be an overview of the findings of the entire project.

The subject of this introductory part concerns the planning that led to the initiation of the project. An appreciation of main issues concerning the performance of outer wall systems was provided. The main assumption made was that water will eventually breach the cladding system somewhere. The issue then is not how water can get in but how water that gets in behind the cladding is able to drain, how much of the water that is introduced into that space is likely to be retained, and the rate at which the retained moisture dissipates.

The selection process for wall systems to test involved a series of compromises. To simplify the experimental task of maximizing the information gained, relatively non absorbent finished cladding materials were selected for this study. Out of the many possible choices available, systems were chosen that would represent some of the more important cladding systems currently used in residential construction. It was planned that, given limitations in budget, these tests would provide a glimpse of the ability of broad classes of cladding, with and without defined drainage cavities, to manage moisture that penetrates them. Supplementary tests to help explain the mechanics of moisture removal were also planned.

RÉSUMÉ

Les conclusions de ce rapport de projet ont été divisées en une série de « parties », le présent rapport étant le premier de cette série. En raison de la quantité de détails considérables qui entrent dans la composition du rapport sur les nombreuses variantes de mur qui ont fait partie de l'essai, on a jugé qu'il était plus facile pour le lecteur de voir chaque section du travail de façon séparée. Le rapport final de la série fait le survol des conclusions du projet en entier.

Le sujet de cette partie de l'introduction porte sur la planification qui a mené au lancement du projet. Une évaluation des principales questions concernant la performance des systèmes de façade de mur extérieur a été présentée. La principale hypothèse était que l'eau pénètrera éventuellement quelque part dans le système de parement. La question consiste alors à savoir non pas comment l'eau peut pénétrer, mais comment l'eau qui arrive derrière le parement peut se drainer, le volume d'eau s'infiltrant dans cet espace qui sera vraisemblablement retenu et la vitesse à laquelle l'humidité retenue se dissipe.

Le processus de sélection des systèmes de mur à mettre à l'essai supposait une série de compromis. Afin de simplifier la tâche expérimentale et de maximiser l'information obtenue, des matériaux de parement finis non absorbants ont été choisis pour cette étude. Parmi le très grand nombre de choix possibles, des systèmes ont été choisis qui représenteraient certains des plus importants systèmes de parement actuellement utilisés en construction résidentielle. Compte tenu des limites budgétaires, on a prévu que ces essais donneraient un aperçu de l'aptitude de grandes catégories de parements, avec et sans cavités de drainage définies, de gérer la pénétration d'humidité. Des essais supplémentaires visant à aider à l'explication des phénomènes contribuant à l'enlèvement de l'humidité ont également été prévus.

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ACKNOWLEDGEMENTS

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Special thanks are due to John Edgar (Sto Corp), Peter Culyer (Dryvit Systems Canada), and Gary Campacci (DuROCK Alfacing International Ltd.) for donating the EIFS test walls for retesting in this study.

Also acknowledged are Fadi Nabhan at CCMC and Frank Lohman at the NRC Code Centre who acted on the steering committee and reviewed the documents.

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PREFACE

CMHC proposed that a series of drainage tests of exterior cladding assemblies be undertaken to produce data to quantify the ability of several types of cladding and methods of application on wall systems to manage and evacuate water that has intruded behind them. The test program has concentrated on the drainage characteristics of the tested systems, the amount of water that is retained and the drying ability of the cladding tested. The present report details the experimental plan devised.

The reports are organized by the different phases in the project and by the wall types tested for drainage with additional supplementary tests done in support of the work. In summary, the different “Parts” of reporting in this project are:

Part 1 - Experimental Approach and Plan
Part 2 - Testing and Measurement Methodologies.
Part 3 – Drainage Testing of EIFS Wall Systems
Part 4 - Drainage Testing of Walls with Vinyl Siding
Part 5 - Drainage Testing of Walls with Wood-based and Fibrous Cement Siding
Part 6 - Air Flow Characteristics of Wall Systems Having Drainage Cavities
Part 7 - Air Leakage and Vapour Permeance of Joints in Some Siding Systems
Part 8 - Summary Report

Reporting has been compartmentalized into this series of “Parts” because of the extensive detail involved in reporting on the many wall variants that have been included. Comparisons were considered more manageable for the reader to face by providing the details separately in each segment of the work.

DRAINAGE AND RETENTION OF WATER BY CLADDING SYSTEMS

Part 1 - Experimental Approach and Plan

1 INTRODUCTION

Numerous occurrences of premature building envelope failure and excessive moisture damage to exterior walls in residential buildings across Canada and the United States are directly related to the use of exterior claddings that represent the "face seal" approach to prevent of rain penetration. Some jurisdictions, such as the City of Vancouver, have mandated the use of exterior claddings which incorporate "rainscreen" design principles; that is, the exterior walls contain both a first line and second line of defence where the latter has a capillary break to permit drainage, and flashing to ensure that any water penetration through the cladding will not adversely affect the remainder of the wall assembly. As a condition for acceptance by the Canadian Construction Materials Centre (CCMC) Products Evaluation Service, exterior wall systems must incorporate a second line of defense (unless proven to be unnecessary). This requirement is to ensure that any water penetration through the cladding will not adversely affect the remainder of the wall assembly. CCMC has identified two types of second line of defence suitable for use in conjunction with rainscreen claddings, 1) an adequate drainage cavity of at least 10 mm together with appropriate details to remove water from the wall assembly, or 2) a water proof barrier to be used in conjunction with insulating cladding systems. Evaluation of exterior claddings without one of these two types of second line of defense provisions will require the development of testing and/or modeling and/or field study protocols. The National Building Code of Canada (NBCC) has incorporated similar requirements into the latest edition of the NBCC (2005).

The requirement for a second line of defense raises several important questions for which answers are yet to be provided. What constitutes an effective second line of defense to manage rainwater intrusion? What size of clear cavity between the cladding and the sheathing membrane is adequate for drainage? Is the effectiveness of a particular cavity width necessary to drain water dependent on the cladding material or the sheathing membrane used? Will two layers of sheathing membranes drain water better than a single layer?

CMHC proposed that a series of tests of exterior cladding assemblies be undertaken to produce data that would quantify the ability of several types of cladding and methods of application on wall systems to manage and evacuate water that has intruded behind the cladding. The request was that the study focus on the drainage characteristics of the tested systems. At a minimum, measurement of the amount of water drained and the amount retained by the assemblies was to be made. Funding for this project was provided by Canada Mortgage and Housing Corporation (CMHC).

2 PROJECT DEFINITION

While the title of the Request for Proposals was "Water Penetration Testing of Wall Systems" the scope of the work is more closely aligned to determining performance of walls once the cladding has been penetrated by rain, not on the factors that would permit this to occur. Investigation of the manner that water penetrates particular wall systems is many-faceted both from a testing point of view as well as from an assembly point of view.

This work is part of a more general area of investigation described as the "performance of outer-wall systems in managing moisture" whatever the source of moisture. There are many questions that may be asked, and we are faced with many more issues than can possibly be addressed in one study. The complexity of outer wall system behaviour requires that parametric computer analysis of wall performance will be undertaken eventually. Only then can some questions be answered in more detail. While it is premature to do an analysis of that type now, we can plan to obtain information that can contribute to that work in the future.

Wall systems are expected, as their prime function, to perform durably to protect the interior living spaces from the exterior climate. Successful building systems do this while at the same time act to manage heat, air, and moisture from all sources, whatever the occupancy. As a consequence of the complexity of behaviour, particularly of the outer-wall portion of building enclosures, it is logical to conduct experiments under limited boundary conditions to understand how different systems will behave. With this basic understanding, it may then be possible to more confidently undertake more detailed investigations and parametric analysis of total wall performance involving real weather conditions.

In pursing these simpler behavioural investigations, various questions are raised. These include:

- How well can water drain through the interface between the cladding and the water (or weather) resistive barrier (WRB) applied against the sheathing?
- How much moisture is retained when rain penetration takes place?
- How is the retained water distributed?
- How does the retained water dissipate from the wall and how long does it take to dissipate?
- How might water entering the space behind the cladding penetrate the second line of defense, i.e. the WRB, depending on the method of construction and attachment, and the properties of the WRB?

Once a wall is wetted in some way and drainage of liquid water stops, the further removal of moisture from each test wall involves a complex set of physical mechanisms. The means by which moisture removal takes place from those wetted materials in a wall, without considering the order of magnitude effects, are:

- vapour diffusion inward into the wall cavities,
- vapour and liquid diffusion outward through the cladding material,
- vapour diffusion outward through joints in the cladding,
- vapour diffusion outward through details provided for drainage,
- vapour diffusion outward through the defect through which water entry took place,
- ventilation of the drainage space induced by moisture buoyancy,
- ventilation induced by thermal buoyancy caused by thermal gradients across the wall, and in particular, of materials immediately adjacent to the drainage/ventilation space,
- ventilation through joints in the cladding,
- Wind driven ventilation through applied pressure differences across all openings.

Each of the above depends on characteristics and properties of both the inner and outer wall. The diffusive properties of the inner wall - the WRB, the wood-based sheathing insulation and inner face of a wall can be probably be deduced from existing databases for the purpose of parametric computer modeling. Additional needed information that is not generally available involves most of the detailed questions above. That information includes:

- the air flow characteristics across the joints in the cladding,
- the air flow characteristics across the top and bottom flashing details,
- the air flow characteristics of the drainage/ventilation space,
- the effective vapour permeance of joints in the cladding,
- the effective vapour permeance of the top and bottom flashing details, and in the case of a defect allowing water entry, the air flow and vapour permeability characteristics of the defect,
- The film transfer coefficients for moisture transfer between the materials facing the drainage/ventilation cavity and the air in it.

Different wall systems require different information. Some cases can present problematic choices for the experimenter. In the case of stucco systems, cracks that develop over time can not be evaluated easily in a short experiment involving new walls. Cracks of this nature do develop and can be induced. However, studies of systems of this type require substantial planning and, as a class, are greatly affected by the absorption of water on their exterior surface.

Finally, there is the issue of fasteners. Little is known about moisture entry at fasteners that penetrate the WRB. There is as yet little information of this nature for standing walls except for limited testing involving application of a sustained water head over fasteners through small samples of WRB materials. Again, investigation of this matter under conditions that simulate walls requires a very different level of detail and measurement than needed for draining/wetting studies.

Given the many issues raised, we must limit the investigation to the basic questions that have yet to be answered for most wall systems. These are: the drainage characteristics of drainage and direct-applied claddings, their retention characteristics, the drying behaviour of cladding systems and some of the mechanisms by which that moisture can escape.

3 EXPERIMENTAL DESIGN

3.1 Choice of Cladding Systems to Test

Common cladding systems on the market include stucco, hardboard siding, wood siding, vinyl siding, aluminium siding, EIFS, wood/cement board, plywood paneling, and masonry. Each type of system has unique properties and mode of behaviour depending on the materials and their installation. To meet the intent of the study, which was to gain as much information as possible about different systems, the decision was made to limit the choice to systems that were not very absorbent. Stucco and brick systems were excluded mainly for this reason and because absorbent systems require considerably more investigation to secure useful information. Some assemblies that could have been selected are described below.

Wood-based siding (solid wood and hardboard):

- Applied directly against the wood-based sheathing with one or two layers of WRB.
- Applied on batten strips (of different depths) from 2-3 mm to 19 mm.
- Applied against drainage mats.

Vinyl Siding

- Applied directly against the wood-based sheathing with one or two layers of WRB.
- Applied with insulation materials in the profiles.

EIFS

- Applied directly against the structural sheathing with one or two layers of WRB.
- Applied against drainage mats of various designs, or with special grooves, or adhesive strips. Some manufacturers have even used geotextiles as a drainage mat.
- Using LA-WPB (liquid applied water penetration barrier) with the EPS foam bonded to the LA-WPB with adhesive materials in ways that permit drainage.
- Using EPS foam with textured dimples or other features that provide defined drainage spaces.

Additional choices that go into the makeup of test walls relate to the different types of WRB materials available on the market. These include the following:

- Class C — Asphalt-impregnated cellulose fibre based WRB
- Class P — Polymeric fibrous WRB
- Class PP — Perforated polymeric film
- Class LA — Liquid trowel or roller-applied WRB
- Class M — Micro-porous film WRB

While usually only one layer of membrane is used, some designers prefer to use two layers overlapped to provide a greater degree of protection. Some have even used combinations of two types of WRB.

With regard to the structural sheathing used, OSB and plywood likely dominate use in residential construction. However, glass fibre coated gypsum products and other insulation products are also used.

With all of the above choices available for construction of test walls including the WRB materials used and the sheathing available, this still provides a very large number of combinations for construction of test walls. Since the research budget was limited, the following decisions were made:

- Based on a previous drainage study of EIFS cladding, 6 test walls from 3 manufacturers (2 each) were donated for the CMHC study. These involved use of LA-WPB on OSB sheathing and with the EPS foam bonded to the wall with adhesive ribbons formed by towelling on beads of an adhesive mixture on the back of the EPS foam. These walls represent only one class of EIFS systems on the market; however the technique of construction involved is favoured by industry because they provide drainage and other synergistic benefits.
- OSB sheathing was used for all walls. On the whole, the involvement of the type of structural sheathing has minimal effect on the retention of water by drainage tests of short duration in comparison with the effect of the absorption by materials in the drainage cavity.
- Vinyl, wood-based sidings and wood cement fibre siding constitute the majority of cladding types used in residential construction, and some of each type were included in the plan. Their exterior surfaces, as a class, are relatively non absorbent because of the finishing systems employed.

- With regard to WRB materials, the EIFS walls all involved use of continuous liquid applied membranes to which the EPS foam was bonded using adhesive ribbons. All other walls in this study required mechanical attachment and it was decided that both sheathing paper (of one type) and a spun bonded polyolefin material (SBPO) should be represented. For these short duration tests, it is likely that, since both types are hydrophobic, their other differences in behaviour would not have an important effect on the results. However, to ensure that this was not overlooked, both types were included.
- As there are many options for creating drainage cavities, only a few options were considered. The EIFS walls had 2-3 mm cavities for drainage created by the adhesive ribbons that were trowelled on the back of the EPS foam insulation. The other cladding systems were provided drainage cavities by use of batten strips (19 mm traditionally), and three types of mat systems. All remaining systems were direct-applied and did not have a defined drainage cavity.

3.2 Experimental Plan

The best approach in conducting a multifaceted research program is to ask the most appropriate questions, and then to devise experiments or tests to answer them. There are obviously more questions concerning the performance of these cladding systems than can be addressed, or even answered fully in this study. In additions to variables related to the construction of test walls, there are also procedural questions on test protocols because they may influence the result of a test. A valid question to raise is whether a single test wall can sufficiently represent that class of wall or whether several replicates are needed. The test standard ASTM E 2273-03 requires three test walls of each particular design to be used to account for variability. But, to provide even that minimum number of replicates would result in many more wall tests having to be built and tested, and that minimizes the choice of numbers of systems that could be tested in this exploratory test program.

To simply make and test individual walls of each type is probably appropriate for exploratory work. At this stage, aside from the previous drainage tests on EIFS walls, there was sufficient lack of experience to suggest what number of walls of each type would be most useful to test. Given the limit imposed by costs, in consultation with CMHC staff, it was decided that as broad a selection as possible of different wall types should be made and, from this, some idea of necessary replications might be recommended for future tests.

Further, some system choices were dictated by the availability of some materials. The materials and test walls that were eventually fabricated for the test program are shown in Table 1.

Table 1 Matrix of Drainage Tests Planned

Cladding Type	Number of Walls	WRB	Location of Water Entry	Attachment	Number of Tests
EIFS	6	LA-WPB	F/B	Adhesive Ribbons	12
Vinyl Siding	3	2-SBPO 1-BP	middle middle	2 direct attached 1 direct attached	2 1
Hardboard Siding	3	3-SBPO	F/B middle	2 Mats 1 direct attached	4 1
Wood Siding	3	1 BP 2 SBPO	F/B middle WRB	1 Mat 1 direct attached 1 battens	2 1 1
Cement Siding	2	2 SBPO	middle	2 direct applied	2
TOTALS	**17**				**26**

F/B = walls tested twice, with water trickled down the **front** or **back** of the drainage cavity
SBPO = spun bonded olefin WRB
BP = building paper WRB
LA-WPB = liquid applied water penetration barrier

4 SUMMARY OF TESTS PLANNED

A total of 26 tests were originally planned. The total number of walls (17) investigated in this exploratory study includes the following:

- 6 EIFS walls
- 3 vinyl siding walls (two different profiles)
- 3 hardboard siding walls, two applied on drainage mats, and one direct-applied
- 3 wood siding walls, (two profiles), one on a drainage mats, one on batten strips and one direct-applied
- 2 wood fibre cement sidings (one profile), both direct-applied.

As noted in Table 1, some walls were tested twice because some systems have greater or lesser capability of retaining water depending on how water enters the cavity and where it might be retained. These systems were tested by intentionally directing the flow of water to the back of a drainage cavity (against the WRB) and, after they had been set aside to dry, they were retested with water flow directed down the front of the drainage cavity (on the back face of the cladding). This was done to study the different storage capacity of the surfaces facing the drainage cavity. In the case of direct-applied sidings the water was simply directed to the middle of the space at the top course of siding to see how the water would work its way down through the cladding construction.

In addition to the drainage/retention studies, air flow measurements were made for walls with definite drainage cavities. For siding systems, recognizing that moisture can dissipate through joints in cladding, air flow and vapour flow characteristics were also obtained for selected siding systems. This was done to provide information that contributes to understanding the drying performance of siding systems no matter how moisture got into the space behind them.

5 ORGANIZATION OF REPORTS

The reports on work done for this project are organized by the wall types tested and the additional supplementary tests done in support of the work. In summary, the different Parts of this report are:

Part 1 - Experimental Approach and Plan
Part 2 - Testing and Measurement Methodologies.
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Part 7 - Air Leakage and Vapour Permeability of Joints in Some Siding Systems

The overall results of the entire study are provided in the final Summary Report.

6 REFERENCES

[1] ASTM E 2273-03 Standard Test Method for Determining the Drainage Efficiency of Exterior Insulation and Finish Systems (EIFS) Clad Wall Assemblies. ASTM. West Conshohocken, PA

[2] NBCC (2005) – National Building Code of Canada, IRC. Ottawa.