Ventilation Drying in Enclosure Wall Systems

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Abstract

This paper reports on a three year program of research on the drying potential of natural ventilation in screen-type, enclosure wall systems. The work was initiated by ASHRAE, Technical Committee 4.4, but was also funded by NSF/PATH, the Commonwealth of Pennsylvania and the Hankin Endowment. The work is documented in twelve reports and represents the state-of-the-art at this point in time.

Keywords: Building enclosure, wall systems, screen-type wall systems, ventilation, drying, moisture control

Introduction

Ventilation, natural or otherwise, has been used to replace hot and/or moist air in buildings for thousands of years. By making use of ventilation, the occupants have been cooled and made more comfortable, and moisture-related problems have been avoided or reduced. Ventilation of the building enclosure (e.g., residential roofing systems) has been and still is very common. Ventilated crawlspaces (incorrectly called vented crawlspaces in the building codes) are also common, although the current trend is away from natural ventilation for crawlspaces. Ventilation within above-grade, screen-type wall systems is not a topic that has received much technical attention, at least in North America. Ventilation drying for North American construction methods and climatic conditions has not previously been comprehensively studied, in spite of the fact that moisture-related problems -- often manifested as mold -- are of national concern. Ventilation in particular, and better designed and better built wall systems in general, are part of the solution.

For the last three years an ambitious R and D project on the potential for ventilation drying in screened, above-grade, enclosure wall systems has been conducted. This project, titled "Development of Design Strategies for Rainscreen and Sheathing Membrane Performance in Wood Frame Walls," was initiated and supervised by ASHRAE Technical Committee TC 4.4 "Building Materials and Building Envelope Systems."

Dr. Eric Burnett, Director of the PHRC and Hankin Chair in the Department of Civil and Environmental Engineering and the Department Architectural Engineering at Penn State, was the principal investigator. The project was conducted in collaboration with two other institutions: the Building Engineering Group (BEG) at the University of Waterloo in Canada under the leadership of Dr. John Straube, and Oak Ridge National Laboratory (ORNL) in Tennessee under

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the leadership of Dr. Achilles Karagiozis, a senior research engineer in the Building Technology Center.

Objectives

The stated terms of reference for the project focused on two concerns: first, the nature and relevance of air cavity ventilation and, second, the performance and contribution of the screen-type cladding and the sheathing membrane. A comprehensive program of laboratory and full-scale field testing and computer modeling was called for. The main objective was to develop an understanding of the nature and potential for ventilation drying and to study, in particular, the contribution of sheathing membrane and the screen-type cladding to the overall performance of residential wall systems.

One objective of this project was therefore to generate experimental data on the performance of ventilation strategies and their effect on the overall performance of wood-framed, screened wall systems. The experimental information was to be used to modify (if necessary) and to benchmark and validate computer-based simulation procedures. A comprehensive program of advanced, state-of-the-art hygrothermal modeling was then envisaged, mainly to extend the knowledge to other wall systems and to cover at least six representative climatic areas. These data were then to be used to provide the basis for the development of design guidelines.

All the relevant work was to be documented. To transfer this understanding to industry, design guidelines as well as supplementary, builder-friendly documentation was to be developed. The information generated from this project would serve as input to the new ASHRAE SPC 160P on "Prevention of Moisture Damage." The results from this research project were also to be used to provide material for possible inclusion in the next edition of the ASHRAE Handbook of Fundamentals.

The overall intent was for the results of this R and D and the subsequent deliverables to provide timely and much needed answers to many of the concerns and questions related to screen-type wall systems and, it was hoped, to resolve some very important concerns about enclosure performance.

Opportunities

Right from the outset, it was realized that this ASHRAE initiative represented a unique opportunity for all involved. For instance, this was an opportunity to comprehensively address a topic that was important but virtually unstudied in North America, namely, the potential for ventilation drying in enclosure wall systems. Moreover, the topic, or the variety of the related topics involved, demanded a multi-disciplinary and multi-institutional approach. The scope of the project provided the following opportunities for each participant:

?? At Penn State, the project required the expansion of the Building Enclosure Test Laboratory (BeTL) and the development of a versatile climate chamber. Moreover, it was known that the proportion of the ASHRAE funding allocated to Penn State was insufficient to fund the work involved and that additional support would be needed. Some of this additional funding was provided by the Hankin Endowment, the Faculty of Engineering, and the Commonwealth of Pennsylvania through support for the activities of the PHRC. One consequence has been the development of the new BeTL facility at Penn State which provides a unique capability for building enclosure testing. In addition, and this was an important addition, a complementary research project was funded by the NSF/PATH program.

?? A full-scale, field test facility on the campus of the University of Waterloo in Ontario, Canada, was designed and built by the PI some twenty years ago. Called BEGHUT it has since been in continuous use as a facility for research, development and demonstration (R, D and D), and it has also been significantly expanded and improved. Although the initial RFP did not call for any field studies, the three co-leaders of this project argued that full-scale field experimentation, especially for the observation of actual wind and buoyancy driving forces, was a necessary complement to the program of laboratory testing.

?? Dr. Karagiozis at ORNL is the developer of the **LATENITE / Moisture Expert** software, one of the most sophisticated hygrothermal modeling tools available. The experimental work contemplated in this project would provide a unique opportunity to conduct benchmarking and validation studies of convective flow in wall systems, as well as to incorporate some of the results from the parametric testing.

The ASHRAE Technical Committee 4.4 needs to be commended for their vision in recognizing the scale of the project and the inherent opportunities to add value to both the project and all the participants.

Current "State-of-the-Art"

The work conducted in this R and D projects represents the state-of-the-art. Moreover, it extends the state-of-the-art insofar as sheathing membranes and screen-type claddings are concerned. Given the importance of the building enclosure, especially the above-grade wall enclosure, in relation to human health and safety (mold, etc.), durability (moisture-related deterioration and damage) and homeland security (blast and impact), there is every reason to recommend that a major investment in both R and D on building enclosures and building science education needs to be made.

Execution and Deliverables

Table 1 identifies the tasks involved and their nature, the responsible parties, and the related deliverables. As can be seen, the project involved laboratory experimentation, full-scale field observation, and simulation. Each of the three institutions conducted some laboratory-based experimental work; the field testing was conducted using the BEGHUT facility maintained by BEG/UW. The hygrothermal simulation was largely the responsibility of BTC/ORNL.

Table 1: Project Tasks and Deliverables

Tasks		Type	Institution			Report Number
No.	**Topic**		**PHRC/ PSU**	**BEG/ UW**	**BTC/ ORNL**	
0	Literature review	R	*	*	*	1
1	Properties of relevant materials	EL	*	*	***	2
2	Sheathing membranes	R	***			
3	***Ventilation airflow:***					
3a	Vinyl siding	EL		**		4
3b	Metal, brick veneer, vinyl cladding	EL	***			5
4	Natural ventilation / brick veneer	EF		***		6
5	***Ventilation drying in the laboratory***					
5a	Physical demonstration	EL	***			3
5b	Climate chamber testing	EL	***			7
6	Ventilation drying in the field	EF		***		8
7	***Computer modeling***					
7a	Simulation (CFD and HAM)	M	*	**	***	9
7b	Benchmarking	M	**	*	***	10
7c	Parametric evaluation	M	*	*	***	11
8	***Technology Transfer:***		***	***	***	
8a	Synthesis and guidelines	R	***	**	**	12
8b	Papers and Builder Briefs	R	***	**	**	

Code: **E**-Experimental, **L**-Laboratory, **F**-Field, **M**-Modeling, **R**-Review

To date, the overall project has taken over three years. To fully complete all the work involved, including the final guidelines, papers, builder briefs and theses will probably take another year.

In Table 2 each of the deliverable reports is listed and cross-referenced to each of the tasks in Table 1. From examining the two tables it should be reasonably clear what each report is all about and who was involved. There is little to be gained by providing a series of abstracts for each report; each report is a stand-alone document, and collectively they are a sequenced set of interdependent documents that constitute a body of focused work.

Table 2: List of Deliverable Reports

1. **Review of Literature and Theory** (BEG/UW, Task 0)
   J. Straube, R. VanStraaten, E. Burnett, C. Schumacher

2. **Hygrothermal Properties of Selected Materials** (BTC/ORNL, Task 1)
   A. Karagiozis, K. Wilkes

3. **Ventilation Drying in Screened Wall Systems: a Physical Demonstration** (PHRC/PSU, Task 5)
   X. Shi, C. Schumacher, E. Burnett, J. Straube

4. **Characterization of Airflow Behind Vinyl Siding** (BEG/UW, Task 3a)
   R. VanStraaten, J. Straube, E. Burnett

5. **Characterization of Ventilation Airflow in Screened Wall Systems** (PHRC/PSU, Task 3b)
   J. Piñon, D. Davidovic, E. Burnett, J. Srebric

6. **Field Characterization of Airflow Behind Brick Veneer** (BEG/UW, Task 4)
   R. VanStraaten, J. Straube

7. **Ventilation Drying under Simulated Climate Conditions** (PHRC/PSU, Task 5b)
   X. Shi, C. Schumacher, E. Burnett, J. Straube

8. **Ventilation Drying under Natural Exposure Conditions** (BEGUW, Task 6)
   R. VanStraaten, J. Straube, C. Schumacher, E. Burnett

9. **CFD Simulation of Airflow in Ventilated Wall Systems** (ORNL, Task 7a)
   T. Stovall, A. Karagiozis

10. **Benchmarking of the Moisture-Expert Model for Ventilation Drying** (ORNL, Task 7b)
    A. Karagiozis

11. **Performance of Ventilated Wall Systems as a Function of Climate using Advanced Hygrothermal Modeling** (ORNL, Task 7c)
    A. Karagiozis

12. **Synthesis Report and Guidelines** (PHRC/PSU, Task 8)
    E. Burnett, J. Straube, A. Karagiozis,
    C. Schumacher, X. Shi, R. VanStraaten, J. Piñon, D. Davidovic

Papers, Builder Briefs, etc., to follow.

Outcomes and Conclusions

The project was an ambitious one. The overall objective was to study the mechanics of ventilation in screen-type wall systems and to assess the potential for ventilation drying of these common, above-grade, residential wall systems. Screen-type cladding and the exterior membrane to the exterior sheathing are two very important constituent layers in these multi-layer residential wall assemblies. Much of the work has relevance to building enclosures other than wood-frame house construction.

As a consequence of this project, it is recommended that when a screen-type cladding is used, ventilation as a means of contributing to the drying process should be provided when it is feasible and practical to do so,. Since gravity drainage must always be provided in screen-type wall systems, it requires little additional effort or cost to facilitate ventilation behind the cladding. It should be noted that gravity drainage is a necessary requirement but is not necessarily sufficient to enable drying to occur. In many instances, ventilation or convective air movement may be the only means of fully drying the outer portion of the wall.

The project has proven to be a highly productive exercise in international, multi-disciplinary and multi-institutional technological research, development and demonstration (R, D and D). It also demonstrates that the support, financial and otherwise, of the funding agencies can be leveraged to good effect and that some universities are uniquely positioned to add value to R, D and D initiatives.

One important consideration has been the fact that while most ASHRAE members have some knowledge of the necessary thermodynamics and fluid mechanics, they do not usually design walls. The professionals who do design walls or who are responsible for choosing wall systems do not have this knowledge or the relevant education and many of them, especially architects and builders seem unlikely to develop it, at least within the near future. One issue is how best to bridge this disconnect. This project does provide some assistance in that much of the relevant theory is assessed from the standpoint of enclosure design and building science, and the guidelines and supplementary documentation will be addressed to these different audiences.