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ENVIRONMENTAL SEPARATOR PERFORMANCE MATRIX METHODOLOGY

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ABSTRACT

This paper presents a methodology for systematically assessing the performance of environmental separators. The design of well performing building envelope systems has become a more complex and difficult task since traditional methods and materials have been displaced by technological innovation. In a world where more new materials and components are emerging every year, this increasing choice demands an effective means of understanding the fundamental behaviour of competing alternatives. An algorithmic approach is not feasible, since the vast number of rules and exceptions would rapidly obscure the underlying logic.

In the academic environment, the methodology is supplemented with information provided online by the Institute for Research in Construction, National Research Council of Canada Web site. In particular, access to Canadian Construction Materials Centre evaluation reports and related publications, augments requirements set forth in the National Building Code of Canada. It is also possible to consider additional criteria emerging from building science research or other jurisdictions.

A key aspect of the methodology is the graphic representation of the performance matrix, which indicates the adequacy of the separator(s) under review and also depicts material multi-functionality and the degree of redundancy associated with critical control functions. An example application of the methodology is presented to demonstrate its utility in separator performance assessment.

1. INTRODUCTION

The basic requirements for acceptable environmental separator performance are well established [1]. Over the past decade, increasingly sophisticated tools for the design and performance assessment of separators have been developed to quantify their hygrothermal behaviour [2]. These advances are significant and ongoing, providing building science practitioners with valuable means of contributing to the improved reliability and performance of building envelopes.

Parallel to these efforts, researchers have advanced rigorous analytical techniques for functional envelope design [3]. Further, shared conceptual models of the design process have explored means of enabling the integration of envelope performance measures within the larger design framework [4].

However, the concepts expressed in the building science lexicon describing environmental separator behaviour continue to elude many designers, builders, and more importantly, students in professional programs for building design. Reasons for this situation include the complexities of material behaviour and interactions, and the abstract nature of concepts such as redundancy in critical control functions [5]. This paper presents a methodology designed to qualitatively explicate separator design and performance assessment.

2. METHODOLOGY

The ESPM methodology is based on practical assumptions and adheres to a logical formulation of the design/assessment process.

2.1 Assumptions

Application of the ESMP methodology assumes an entry level of knowledge or competence by the student or practitioner. Typically, facility in building science and familiarity with concepts of moisture migration, heat transfer, air leakage and solar radiation effects on building materials and assemblies is prerequisite. Given this understanding, the key assumptions for application of the ESPM methodology are:

1. Workmanship and materials are imperfect. Inaccuracy and inconsistency of workmanship and materials, in conjunction with variable weather conditions during construction, often result in buildings which only approximately fulfill their design intent.

2. Environmental separator design strategies employing redundancy of critical control functions are in most cases superior to '*perfect barrier*' strategies. In general, they are less expensive and more forgiving to construct, since permissible variations in the quality of materials and workmanship are greater than those required by a '*perfect barrier*' approach.

3. In cold climates, experience indicates that when the requirements for the control of moisture migration have been satisfied, the other control requirements are either simultaneously satisfied, or more easily satisfied, than if moisture management is not addressed at the outset.

In practical terms, within the context of a cold climate and Canadian construction practices, these assumptions guide users to assume flawed construction that must be compensated with redundant control measures focused on moisture management.

2.2 Performance Concepts Rationale

This methodology is premised on the qualitative representation of key performance concepts describing thresholds of performance, material behaviour and interactions between materials. The following terms explain how these concepts are represented within the methodology.

Compliance - The term ‘compliance’ refers to how well a separator satisfies intended, or expected, thresholds of performance established by codes, standards, and professional practice. Compliance may be described as: (i) exceeds; (ii) fully satisfies; (iii) partially satisfies; or (iv) inadequate, with respect to a given code or standard.

Multi-Functionality - A material may be uni-functional, such as a structural element, or it may address more than one required control function resisting imposed physical phenomena. Multi-functionality may be described as either: (i) single material addresses all separator control functions; or (ii) material primarily addresses one control function (*first line of defence*) and contributes to another control function(s), (*second line of defence*).

Redundancy - A separator with more than one ‘*line of defence*’ against imposed phenomena may be redundant with respect to one or more critical control functions. The degree of redundancy may range from: (i) resistance to each imposed phenomenon is distributed across all materials in the assembly (fully redundant); to (ii) resistance to each imposed phenomena correspondingly addressed by individual materials within the assembly (non-redundant, hence each material represents a ‘*perfect barrier*’).

Contribution - A material may improve or enhance the performance of another material or assembly of materials without displaying multi-functionality or explicitly adding to redundancy. For example, an air barrier membrane may reduce air movement through an air-permeable insulation material, improving its thermal effectiveness but not contributing to the nominal thermal resistance of the assembly.

The performance matrix is intended to apply these concepts to graphically convey:

1. Minimum requirements for acceptable separator performance;
2. Compliance of a candidate or existing separator assembly with respect to established requirements;
3. Behaviour of multi-functional materials; and
4. Degree of redundancy with respect to critical control functions provided by an arrangement of materials comprising the environmental separator.

Performance matrix conventions are illustrated in Figure 1. Using a square matrix to compare the required critical control functions against those provided by the materials comprising the separator assembly, it is possible to represent compliance, material multi-functionality and the degree of redundancy, depending on the nature of material interactions.

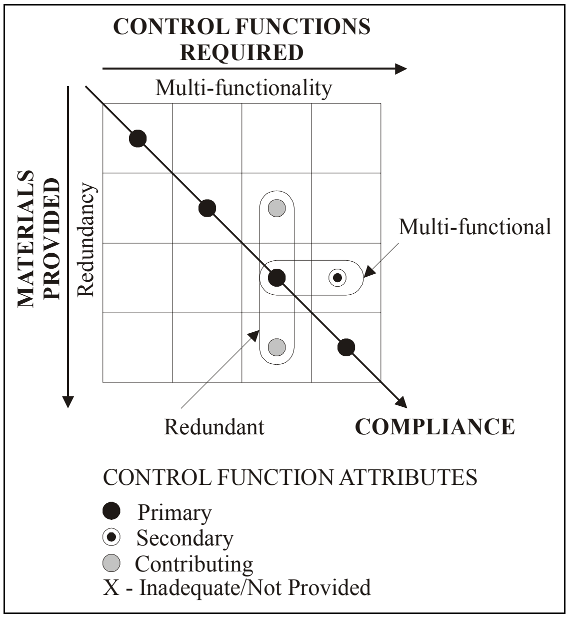

Figure 1. Performance matrix conventions.

The procedure for applying the ESPM methodology is discussed within the context of the following example application.

3. EXAMPLE APPLICATION

The following example describes how the performance matrix methodology is applied to a particular separator assembly.

3.1 Establish Environmental, Exposure and Occupancy Conditions

This first step involves reviewing climatic data, the exposure of the separator to weather phenomena and the occupancy of the space enclosed by the separator. Soil conditions, topology and hydrology are additional considerations important to the design of below-grade envelope assemblies.

3.2 Identify Critical Control Functions

The essential elements of an effective building envelope in a cold climate must address requirements for: (A) structure; (B) interior finish; (C) vapour movement; (D) heat flow; (E) air leakage; and (F) cladding (primarily moisture management). Special requirements for fire and sound separation may also apply.

3.3 Propose Candidate Design or Render Existing Separator Design

In this example, consider an exterior wood-frame wall located in a cold climate, as depicted in Figure 2. This wall section could be from an existing design, or a proposed design. The section is drawn to a reasonable scale, then each material is sequentially numbered from inside to outside, or vice-versa.

3.4 Assign/Identify Primary, Secondary and Contributing Control Functions

Using the critical control functions identified in section 3.2 as a guide, the primary, secondary and contributing control functions for each material or component forming the assembly are assigned a corresponding control function label (in this example, A-F). This information is transferred to a performance matrix, as depicted in Figure 3. Guidelines for fundamental material interactions have been developed and remain widely available [6].

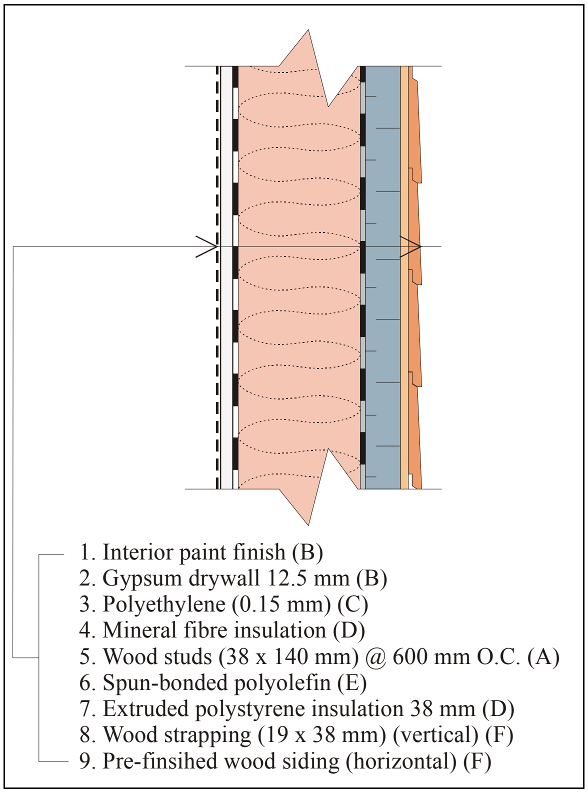

Figure 2. Example wall section.

The control functions provided are listed in the first column corresponding to the materials comprising the separator assembly, as identified in the second column. The required control functions are listed along the top row of the matrix. A pair-wise comparison against the corresponding control functions provided confirms compliance (this normally results in a continuous entry of solid circles across the diagonal of the matrix). If any of the requirements are inadequately controlled, or no explicit control measure is provided, this is indicated by an "X" (assume in this example that all of the primary control functions are satisfied). Then, secondary and contributing control functions are assigned to each of the components of the assembly, and commentary notes are used to describe their behaviour and interactions. The material's numerical label precedes each note, and the material(s) with which it is interacting is identified within the commentary by parentheses.

NOTE: Additional requirements, such as fire and acoustical separation, may be added to this matrix, if applicable. Required control functions may also be further subdivided into distinct physical mechanisms.

		REQUIRED						
PROVIDED	**MATERIAL**	Structure	Interior Finish	Vapour Movement	Heat Flow	Air Leakage	Cladding	**Commentary**
(**A**) Structure	**5**	●						
(**B**) Interior Finish	**1**		●	○				1 - Reduces vapour pressure across (3).
	2		●			○		2 - Reduces air movement across (4).
(**C**) Vapour Movement	**3**			●		○		3 - Reduces air movement across (4).
(**D**) Heat Flow	**4**				●			7 - Reduces condensation potential inside (4) 7 - Protects/supports spunbonded polyolefin (5). 7 - Contributes to rain-screen cladding (8, 9).
	7			⊙	⊙	○	○	
(**E**) Air Leakage	**6**					●	○	1 - Contributes to cladding performance.
(**F**) Cladding	**8**						●	
	9						●	

● Primary ⊙ Secondary ○ Contributing X - Inadequate/Not Provided

Figure 3. Performance matrix assessment for example wall section.

3.5 Assess Separator Performance

First, it is important that the critical control functions initially established, (A-F), have been adequately satisfied.

Second, the degree of redundancy (or factor of safety) must be assessed. For a cold climate separator, the control of moisture migration is most critical. It is noted that the interior paint finish contributes to the control of vapour diffusion. The drywall contributes to the control of air leakage and along with the polyethylene vapour barrier, reduces air movement across the wall cavity insulation (thus contributing to the air barrier system function). The extruded polystyrene is a multi-functional material providing 3 degrees of redundancy: i) as a secondary thermal insulation material, it reduces condensation potential within the insulated cavity; ii) it supports the spun-bonded polyolefin air barrier membrane and protects it from ultraviolet degradation, especially during construction; and iii) it serves as a drainage plane for the rain-screen cladding, forms part of the pressure-equalization chamber along with the strapping, and resists vapour movement from the exterior when the wood siding is wet and exposed to solar radiation. The spun-bonded polyolefin contributes to cladding effectiveness by serving as the primary air barrier windward of the insulated wall cavity.

Based on these interactions, it is possible to conclude that this example envelope assembly will perform adequately, and provides a reasonable degree of redundancy (factor of safety). This methodology can also be applied to comparisons of competing alternatives to graphically render differences in performance.

3.6 System Integration Considerations

The job of building envelope design does not end at the workstation. Issues concerning whole building systems integration continue to challenge the building industry and presently remain beyond the capabilities of this methodology. However, the rational integration of building envelope systems has been explored [7], and current developments within the building science community may soon result in accepted conventions for explicitly predicting and representing the performance of integrated building envelope systems. But the vital process of moving from the construed to the constructed continues to rely more on experience and heuristics, than on quantitative measures and analytical techniques.

4. CONCLUSIONS

The ESPM methodology provides a graphic means of translating sophisticated concepts of environmental separator performance to a variety of users within the construction industry, particularly students.

The methodology aids in reducing the complexity associated with representing the performance attributes of a particular separator assembly within the context of climate, exposure and occupancy conditions.

It should be recognized by advanced building science practitioners that designers and contractors require simpler, and preferably graphic, means of conveying different performance qualities among competing separator alternatives. This is especially critical when material substitutions are contemplated.

The methodology does not diminish the need for continued research and development of performance models, rather it attempts to distill the results in a manner which is more compatible with the information needs of the construction industry and educational sectors.

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