The Impacts of Green Building Strategies on the Durability and Performance of Building Enclosures

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ABSTRACT

Over the last 10 years the concept of green buildings has become an important, and an increasingly large part of building design and construction. The success of LEED, and similar rating system, (both in terms of environmental performance, and more conventional evaluation criteria) have demonstrated the benefits of green design. The well-publicized success of green buildings reinforces demand for more green buildings and requires that all design professionals have, or purport to have expertise in this area. While the impact of sustainable design and of green building rating systems will no doubt be positive over the long term, there may be dangers associated with the rapid application of these systems and associated green design strategies involving the use of innovative materials and technologies.

Specifically, the question of whether the application of specific green design strategies may result in problems of building durability and performance has been raised. Of particular concern is the potential for inadequate building enclosure performance. A recently published paper on the subject of building enclosure commissioning focuses on a LEED Platinum building in the US and makes a direct connection between building green and a range of identified building enclosure problems.

The history of earlier attempts to improve energy performance in buildings can provide useful lessons for green design. The implications of increases in insulation levels and increases in air tightness for building performance, and in particular on enclosure performance were often not fully understood, resulting in a range of problems.

This paper will present the results of an investigation into the implementation of green building strategies and their effects on building enclosure durability and performance. Various green building rating systems will be reviewed and the strategies typically applied to achieve specific ratings will be analyzed. Based on surveys of practitioners, case studies of completed green buildings, and practical experience of building enclosure design and construction the positive and negative impacts of these practices, potential or actual, will be documented. The conclusions of the study and recommendations for improving green building strategies and communication between building enclosure practitioners and green building designers will be presented.

This paper is based in part on research carried out for a study commissioned by CMHC on the subject of green buildings and durability. Limitations on the length of this paper have required that detailed discussion that forms part of the larger study be curtailed and that background information and analysis be summarized.

The CMHC study addressed the performance and durability of both the building enclosure and of HVAC systems with an emphasis on residential buildings. The primary focus of the paper is on issues relating to durability and performance of the building enclosure. However, the survey of practitioners provides a wider context for these issues by also identifying a range of other potential impacts of green design. It is assumed the reader will have a basic understanding of the LEED (Leadership in Energy and Environmental Design) rating system and of the integrated design process (IDP).

INTRODUCTION

One of the most significant developments in building design and construction in the last 10 to 15 years has been the increasingly high profile of green buildings. The history of environmentally responsible building design and construction, and in particular of concerns for energy efficiency, dates back to the 1960s. More recent developments differ from earlier green buildings in the range of environmental issues addressed, and in the variety of building types to which green building strategies have been applied. From an initial emphasis on unique and often eccentric alternative buildings, green building has become a more widespread phenomenon, that is now firmly entrenched within the mainstream design and construction industry and which has been applied to many building types. A wide and varied range of green building design tools, rating systems, and programs has been instrumental in transforming green building from a relatively obscure niche to an everyday concern of design professionals, contractors, developers and building owners.

Although it is likely that the overall impact of green design will be positive in terms of reducing the environmental impacts of buildings, concerns have been raised about possible negative impacts on durability and performance that may result from the application of particular green building strategies. A recently published paper on the subject of building enclosure commissioning focuses on a LEED Platinum building in the US and appears to make a direct connection between green building strategies and a range of identified building enclosure problems[1]. Problems have also been identified in a number of other high-profile green buildings[2].

METHODOLOGY

A range of green building rating systems and tools are available to assist design professionals and contractors in designing and constructing green buildings. The characteristics of the different systems reflect regional variations and the specific concerns, goals, and resources of their developers and users. Rather than undertake a detailed assessment of each system and of the green design strategies that would be promoted by each system, a broad comparison was undertaken to identify the principal environmental issues addressed by each system. In particular whether or not the various programs addressed the issue of durability directly or indirectly was reviewed.

Because of its success and acceptance by the design community in Canada and the US, and because of the comprehensive range of green design issues it addresses, the LEED[3] rating system is used in this study as a comparison framework for assessing the environmental impact of green design strategies. LEED is also the focus of the study because of concerns that the processes involved in achieving LEED certification may themselves have negative impacts.

On completion of the review of rating systems, the environmental impacts of green building design strategies were studied in a number of ways:

1. A review of the LEED Reference Guide[4] was undertaken in order to identify the green design strategies typically employed in designing green buildings. The Reference Guide, essentially a user’s manual for LEED, describes each of the credit areas for which points are awarded, discusses the environmental, economic and social issues associated with the issue in question, and provides suggestions for design strategies.
2. Case studies of LEED buildings and other information published by the USGBC (US Green Building Council) and CaGBC (Canada Green Building Council) was reviewed to confirm the strategies employed in LEED certified buildings and to establish the credit areas where

points were most commonly awarded. In addition, more detailed studies of 2 residential buildings were undertaken.

3. Surveys of practitioners and building owners of green buildings were carried out to gain insight into the practical experiences of designers, contractors and building owners with respect to durability and performance issues.

GREEN BUILDING RATING SYSTEMS

The review of 12 green building rating systems confirmed that, although the degree of emphasis may vary, most address the same range of environmental categories covered by LEED. The more comprehensive systems such as BREEAM (Building Research Establishment Environmental Assessment Method) and BREEAM Green Leaf address all of the credit areas covered by LEED. Other systems such as R-2000 and EnerGuide for Houses address a smaller subset of issues.

Systems differ in their level of complexity, and in the level of effort required to achieve compliance or certification. Those that are intended to be applied to larger non-residential buildings generally require significant inputs by architects and engineers. In contrast, residential programs such as R-2000, Built Green, and LEED-H (LEED for Homes) are usually simpler and are typically based on checklists.

Systems differ in their approach to durability and building enclosure design. Although not always explicitly addressed, many systems include provisions that will have the effect of improving performance and durability. Green Globes for example requires the use of “best air and vapour barrier practices” to ensure building enclosure integrity, and also the use of materials that can withstand a range of environmental deterioration agents. A credit specifically dealing with durability has been included in the Canadian version of LEED. This requires development and implementation of a durability plan based on CSA Guideline on Durability in Buildings[5].

Programs that are applied to smaller residential buildings tend to be based on prescriptive requirements and often have provisions that relate directly to durability. The Built Green programs require the use of materials with long service lives. LEED for Homes also deals with durability by requiring development and verification of a durability plan for materials and recourses.

Table 1 Comparison of Principal Green Building Rating Systems

	Environmental Performance Criteria Categories						
ASSESSMENT TOOL	SITE SUSTAINABILITY	WATER	ENERGY	NATURAL RESOURCE USE	INDOOR ENVIRONMENTAL QUALITY	PROCESS / MANAGEMENT	POLLUTION /EFFLUENTS
LEED NC	X	X	X	X	X		
BREEAM (UK)	X	X	X	X	X	X	X
GREEN GLOBES		X	X	X	X	X	X
GBTOOL		X	X	X	X	X	X
R2000		X	X	X	X		
ENERGUIDE FOR HOUSES			X				
ALBERTA / BC BUILT GREEN		X	X	X	X	X	X

REVIEW OF LEED RATING SYSTEM

A more detailed review of the LEED rating system was carried out. Each of the performance categories (Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality) was reviewed and the suggested design strategies to achieve each credit area were identified. The purpose of the review was to identify strategies that could potentially have a negative impact on durability and building enclosure performance. In the case of many credit areas there is little or no direct or indirect connection between the applicable strategies and building enclosure design and durability. For example, Credit SS 4.1 (Public Transportation Access) provides a point for locating the subject building in proximity to existing public transit routes. In other cases, there may be potential for indirect impacts where application of particular materials or technologies may have unforeseen impacts on other building components or systems. Finally there are strategies that could potentially affect enclosure performance and durability directly. For example a particular material might be selected for its green building characteristics but could fail in some other performance category or prove to be less durable than conventional alternatives. The following sections summarize this analysis.

Sustainable Sites

Credits SS 6.1 (Stormwater Design: Quantity Control) and SS 6.2 (Stormwater Design: Quality Control) deal with stormwater management with a view to reducing the impacts on municipal stormwater infrastructure. Strategies to achieve these goals include reducing or eliminating impervious surfaces and on-site sub-grade piped drainage systems, and retention of stormwater on site. Application of these strategies may result in larger volumes of ground water than would otherwise be the case. If this water is located adjacent to below-grade portions of the building, there may be increased potential for water ingress if waterproofing or dampproofing materials do not provide satisfactory performance.

Credit 7.2 (Heat Island Effect: Roof) addresses the contribution of roofing materials to the urban heat island effect. Mitigation strategies include the use of green (vegetated) roofs or the use of roofing membranes with high reflectance characteristics. Green roofs have been used successfully in Europe for more than 30 years but represent a relatively recent technology in North America. Europeans have developed an extensive knowledge base in relation to green roofs and have also developed roofing products specifically for use in green roof systems. In theory when properly constructed with appropriate materials, green roofs can last longer than conventional roofing systems as the membrane is protected from UV light and extreme temperature fluctuations. However the degree of risk associated with roofing increases as systems become more complex, when designers and contractors work with new materials, or when conventional materials are used in new assemblies.

The use of highly reflective roofing membranes may also create problems for durability and performance if achieving this reflective characteristic becomes the most important selection criteria at the expense of other performance requirements.

Water Efficiency

Strategies in this performance category seek to reduce the amount of potable water used within buildings and for landscape irrigation. Most of these have little or no impact on performance or durability. One area of potential conflict relates to credit WE 1.1 and 1.2 (Water Efficient Landscaping), which promotes strategies to reduce potable water use for landscape irrigation. A suggested strategy to achieve this point is the use of harvested rainwater for irrigation. Changes in roof form or detail design to facilitate the collection of rainwater from roofs and the storage of this rainwater could potentially impact roofing performance. Additional risks may result from storage of large volumes of water within or below the building.

The storage and use of collected stormwater for other non-potable applications and sewage conveyance are possible strategies that could be applied to achieve credits WE 2 and 3 (Innovative Waste Water Technologies, and Water Use Reduction respectively). Although a number of housing projects have used stormwater for toilet and laundry purposes, the points associated with these credits can be more easily achieved through the use of more conventional technologies such as low-flow plumbing fixtures.

Energy and Atmosphere

Strategies in the energy and atmosphere design category aim to reduce energy consumption in buildings and to promote the use of alternative green energy sources. Improvements in energy efficiency are typically achieved in the first instance by reducing energy loads within the building. Following this, improvements can be achieved by either improving the efficiency of mechanical and electrical systems or by improving the performance of the building enclosure. Strategies that focus on improving enclosure performance have potential to affect building durability and enclosure performance.

These strategies will typically involve controlling heat, air, and moisture movement within the building enclosure. In some cases improving thermal performance will simply involve increasing insulation thickness without any significant changes in the overall enclosure assembly design. In other instances it may be necessary, for example, to modify a conventional framed wall assembly to add additional insulation on the exterior. While this may reduce heat loss, it may result in indirect impacts as a result of changes in the method of sheathing attachment, location of air and moisture barriers, and in the detailing of interfaces with windows and other penetrations. The construction industry in general, and residential construction in particular, are based on the use of standard practices and the use of standard details. Changes to these practices increase the risk of failures as a result of design, construction or communication errors.

Materials and Resources

This design category deals with the nature and sources of the materials used in the construction of buildings. Suggested strategies include increasing recycled content, reuse of materials and buildings, and diverting construction waste. The use of “green’ materials is one aspect of green design that has drawn criticism from some sections of the construction materials supply industry. It has been argued that LEED may inadvertently encourage the use of unsuitable and non-durable materials at the expense of robust long-lasting traditional materials. In an extreme and hypothetical example, the use of a cladding material made from recycled cardboard might assist in achieving points, whereas use of masonry brick would not. As is the case in other performance areas, levels of risk may increase if strategies encourage or promote the use of new and innovative, but insufficiently tested materials.

In practice however, points in the materials and resources category are often gained by using conventional materials that happen to have the appropriate environmental profile. For example, almost all steel used in construction has a high recycled content. Concrete with fly ash or other supplementary cement materials, and many gypsum board products also contribute to recycled content points.

Credit MR 1 (Building Reuse) addresses the reuse of the structural and building enclosure systems of existing buildings. It provides points for maintaining specific percentages of key building systems including structure and shell. There is clearly a potential for this strategy to affect building performance if it encourages the retention of building enclosure components that, because of their age, are not functionally adequate. However, replacement of outdated components such as windows is encouraged, so windows and non-structural roof components are excluded from the calculation of this credit. In addition, this approach is based on the reuse of an existing building, and assuming an appropriate level of upgrading, it can be considered to promote durability, and enhance the performance of the existing building.

Credit MR 3 (Resource Reuse) promotes the reuse of building materials and is another strategy that has potential to affect building durability and performance. Most building materials have finite service lives after which they no longer provide acceptable performance. Although it may be possible to refurbish certain materials to extend their service life, the resulting materials may not have the same service life or performance characteristics of comparable new materials. Problems may arise if these limitations are not recognized and designs adjusted accordingly.

As mentioned above, strategies to achieve points for use of materials with recycled content (MR 4, Recycled Content) may affect durability if they promote the use of innovative, but insufficiently tested, materials or assemblies for building enclosure systems. In practice however, most materials of this type tend to be used as finish materials and substrates in building interiors and rarely in building enclosure assemblies.

Indoor Environmental Quality

Credit EQ 4 (Low Emitting Materials), establishes volatile organic compound (VOC) limits for a range of construction materials including adhesives, sealants, paints, and composite wood products. There are potential impacts on durability resulting from the application of this strategy, such as reduced adherence of some water-based adhesives. However, impacts on building enclosure durability are limited as the credit is only applicable to materials used within the building’s interior. Materials such as sealants and adhesives used on the exterior of the building need not comply with the VOC limits.

Credits EQ 8.1 and 8.2 (Daylighting and Views) deal with natural lighting of the building and visual connections between the building interior and outdoor environment. EQ 8.1 requires minimum levels of natural light. Achieving these levels may involve manipulation of building form to increase the building perimeter and increasing the area of glazing relative to wall area. Depending on climate and window orientation, adding glazed areas while still complying with the minimum energy performance requirements of Prerequisite 1, and possibly Credit EA 1, may require the use of high performance glazing. This may create a potential for building enclosure performance issues if the required glazing systems do not have water-management performance appropriate for their location. In addition, the requirement, under this credit, to exclude direct sunlight may result in the use exterior shading devices with potential negative impacts on enclosure performance due to a need to penetrate the building enclosure in order to structurally support the sunshades.

CASE STUDIES

Two buildings, a high-rise residential building in North Vancouver and a low-rise, mixed-use building in Calgary, were studied.

Case study building 1, high-rise residential building, North Vancouver, BC. This building achieved a LEED Certified rating.

Case study building 2, low-rise residential / commercial building, Calgary, AB This building achieved a LEED Certified rating.

The Silva is a 16-storey high-rise residential building located in North Vancouver, BC. The building has achieved 31 LEED credits earning a Certified designation (LEED V2 USGBC).

Although high-rise building incorporates some significant green building features, in common with many LEED Certified buildings, it does not differ significantly from conventional residential buildings of the same type. Many of the LEED points acquired were achieved for the use of materials or building features that are commonly found in similar non-green condominium buildings. For example, credits for the use of materials with recycled concrete are achieved for use of concrete with fly ash content, and the use of reinforcing steel and steel studs with recycled content. While these materials clearly have environmental merit they also represent conventional practice in construction and their use should not result in increased risk of durability or enclosure performance problems.

Recent experience of building enclosure problems has resulted in awareness in all sectors of the construction industry in BC of the range of potential problems of durability and possible contributing factors. These will apply equally to green and non-green buildings, and it is difficult to see that the green features at the building would make an appreciable difference to the overall performance or durability of the building.

The building's cast-in-place concrete exterior walls are likely to be a durable element although their thermal performance will likely not be significantly better than that of similar conventional buildings. It should also be noted that the thermal bridging associated with this form of cast in place concrete construction may result in cold interior surfaces at floor and ceiling levels which may in turn result in condensation and potential mould growth.

The second building studied, The Vento, is a low-rise mixed-use development located in the Bridges neighbourhood of Calgary. The building, which contains 22 town homes located above commercial space, was completed in 2006. It has been designed to achieve a platinum rating under LEED Canada New Construction (NC) 1.0[6].

The building incorporates a wide range of green design strategies including development of a durability plan to achieve Credit MR 8 (Durable Building). A number of the strategies employed, such as the use of collected rainwater for toilet flushing, are innovative and can be considered to involve a degree of risk compared to a typical non-green residential building. However, many of the building's other environmental goals are achieved through the use conventional materials and technologies. For example, the improvement in building energy performance is in part attributable to the design of the exterior walls that incorporate additional thermal insulation. The materials used, fibreglass batt and rigid insulation, are conventional materials commonly used in construction.

Points were achieved for the use of materials with recycled content, regional materials and rapidly renewable materials. Many of the materials in question including all of the rapidly renewable materials were used in the building interior. Exterior cladding materials which also contributed to these points include wood, cementitious siding, and brick. Again while these may be environmentally sound materials their use represents conventional design and construction practice and does not carry any greater risk of problems.

The primary building characteristics that will affect durability and enclosure performance are the use of rainscreen wall assemblies, the quality of design and construction of enclosure assemblies and the building form, rather than specific green features of the building.

SURVEY OF DESIGNERS AND CONTRACTORS

In order to establish a practical perspective on the issue of green buildings and durability, and to investigate the impact of commonly applied green design strategies a survey of practitioners was carried out. Separate survey questions were developed for designers and contractors, and for building owners and property managers. The results of the survey also confirmed that the design strategies identified in the analysis of LEED described above are in fact the strategies being employed in the design and construction of green buildings. Problems experienced by respondents also mirrored many of those identified in the theoretical analysis.

The survey was sent to a total of 230 architects, engineers, contractors, consultants, building owners, and property managers. A total of 67 responses were received from consultants and contractors. The majority of responses were from architects (24) and engineers (18). Other respondents included contractors, developers, environmental building consultants, energy management consultants and designers.

The use of new or innovative materials has been identified as a potential cause of durability or performance problems. Respondents were asked if they had specified or used innovative materials or technologies in order to achieve LEED points and if so, in what areas of the building these had been used. Responses indicated that in the case of innovative materials, interior finishes accounted for the largest number, but use of innovative building enclosure materials was also significant. It should be noted that respondents differ in their definition of what constitutes an innovative material. For example a number of respondents identified TPO roofing membranes as being innovative.

Use of innovative technologies was most common in the case of plumbing and storm water management systems. Also significant was the number of instances of innovation in the case of roofs, and the use of membranes with high albedo characteristics. Specific innovative technologies relating to the building enclosure included, low-e glazing, sunshades, passive solar systems and living walls.

A follow-up question asked if the use of innovative materials and technologies increased the risk of durability or performance problems. Eight of the 67 respondents identified a potential for durability problems, and eleven a potential for building enclosure performance issues. Several respondents expressed the opinion that there were less risks associated with green building due to the level of additional design effort involved in designing green buildings, and the likelihood that problems would be identified and solved in advance through an integrated design process (IDP). It was also suggested that the fact that architects and engineers were unfamiliar with innovative materials would result in more research and investigation of performance during the design stage of the project. Many more respondents made the point that the key issue is the appropriate use of materials whether green or conventional. Specific problems relating to building enclosure durability and performance include:

Risks associated with technologies without extensive track records.

The inter-relationship of innovative mechanical (HVAC) systems with the building enclosure.

Selection of inappropriate roofing membranes in green roofs

SURVEY OF OWNERS AND MANAGERS

A second survey of a smaller group of owners and property managers of green buildings was undertaken by means of telephone interviews. A range of questions was asked and responses recorded along with other observations and opinions.

The respondents, in most cases working for institutional or commercial owners with large building portfolios, had typically been involved with significant numbers of green buildings. In total the respondents had experience with approximately 30 green buildings. In all cases the organizations involved owned a range of buildings, both green and conventional, and the respondents were therefore in a position to make comparisons between the performances of both. However, the point was made a number of times that the green buildings have typically been operational for a relatively short period of time and that this must be considered in making comparisons. The oldest green buildings had been operational for 10 and 11 years.

The buildings discussed incorporated a wide range of green design strategies. Almost all incorporated green materials, typically used in the interior of the buildings as finish materials, or in millwork. Where green materials were identified as being used on the exterior of the building, further questioning confirmed that the materials in question were in most cases conventional materials with particular green characteristics. A number of respondents also mentioned that their buildings employed a strategy of omitting interior finish materials in order to avoid the environmental impacts associated with those materials. All buildings incorporated energy efficient HVAC systems, and almost all included innovative stormwater management systems. Stormwater systems included rainwater collection, retention tanks, and use of collected water for greywater use within the building. Bioswales and constructed wetlands were also used. A number of buildings incorporated building integrated photo-voltaics. Many buildings used low-flow plumbing fixtures including dual flush toilets and waterless urinals. Strategies to increase daylighting, sometimes integrated with lighting controls, were used in a number of the buildings discussed.

In almost all cases respondents had experienced problems with some of the green building strategies employed. In some cases the same problems were identified by a number of owners, for example issues relating to low water consumption toilets and acoustic problems in buildings where interior finishes had been omitted. Table 3.1 below summarizes the problems identified.

One owner with 10 buildings indicated no problems with green building features with the exception of a problem related to exterior paving material.

Respondents were asked if, in their experience, there was a greater level of problem with green buildings they were involved with when compared to conventional buildings. In most cases the response was “no”. A number of qualifications were noted. In many cases, the green buildings were recent buildings and were operating with relatively new equipment and systems. Some of the comparison conventional buildings were older and were experiencing a range of issues associated with older equipment and systems. One respondent believed that the green buildings had improved levels of durability and performance as a result of the quality of materials and equipment used. However, it was apparent that in this case a ‘flagship’ green building was being compared with more utilitarian conventional buildings. In the case of one building, the respondent indicated that levels of problems were greater than in a conventional building. The issues in this case appeared to specifically relate to green building strategies.

Table 2 Summary of identified problems with specific green building strategies.

Strategy	Problem	Comment
Low water consumption toilets / dual flush toilets	User complaints	A common problem.
Waterless urinals	User complaints of odours. Need for frequent cartridge replacement in high use facilities.	A problem in a number of buildings
Chilled floor slabs	User complaints regarding comfort – building too hot or too cold.	
Daylighting strategies	Excessive heat gain in highly glazed circulation areas	Not definitively connected to a green building strategy. The use of natural ventilation has been proposed as a solution to this problem.
	Excessive glare.	
Innovative glazing to reduce heat gain.	Performance not meeting expectations.	
Unconventional HVAC systems	Occupant comfort problems	Primarily an issue of occupants not being familiar with overall heating or cooling strategy.
Omission of interior finishes	Acoustic problems	A problem with a number of buildings.
Integration lighting controls	Unsatisfactory performance of controls intended to turn off lights in response to increased daylight levels.	
Use of permeable paving material	Higher maintenance requirements	

With one exception respondents indicated an overall positive experience with green building. There were few green features that respondents would not be prepared to incorporate into future buildings. Specific failures previously identified were discussed but the response was typically to use a different version of the technology or material or to research products more thoroughly.

INTEGRATED DESIGN PROCESS

In addition to the potential negative impacts of particular green building strategies, additional unforeseen impacts on performance may result from the process of applying these strategies in typical design and construction environments.

A number of recent publications have offered critiques of the LEED registration and certification process. In particular, they have highlighted the phenomenon of “point mongering”, characterized by a focus on acquiring points regardless of whether they actually add environmental value, or whether the strategies involved are applicable to the building in question. The perceived value to building designers and owners in having LEED certified buildings may create pressure to acquire points and achieve high ratings. A number of specific issues that may indirectly affect performance and durability have been identified:

- The enthusiasm generated as a result of working on innovative buildings that incorporate new materials and technologies could potentially result in a lesser degree of attention being paid to more traditional concerns. In particular, the often mundane but critically important detail design aspects of building enclosure may be neglected.
- In a similar manner, a desire to be a participating team member and to be seen to be supportive of new approaches and ideas may pressure the building enclosure consultant into a less cautious and less risk-averse approach. Although this may be perceived as supporting the green components of the project, it is not necessarily in the long-term interest of the building.
- The increased complexity of design work associated with the introduction of new materials and technologies may reduce the time available for preparing and coordinating contract documents. A need to research and evaluate large numbers of new products, particularly with a tight construction schedule, may result in incomplete documentation.

However, a counter argument was proposed by a number of respondents to the survey of practitioners. It was suggested that the process involved in designing green buildings, and in particular the integrated design process (IDP), will actually improve detailed design.

- IDP allows for early definition of goals and targets with input from a range of design team participants can provide a basis for subsequent detail decisions relating to material and component selection. Overall durability goals for the building as whole can be translated into explicit performance criteria for specific assemblies which can in turn be referred to if decisions are later taken to substitute materials.
- The integrated design process, as it is based on early participation of specialists, such as the building enclosure consultant, provides an opportunity for communication between key players before major decisions that may affect durability and performance are made. One of the fundamental determinants of building enclosure performance with respect to water management performance is the degree of exposure of various assemblies. Exposure can be significantly affected by building form, orientation, and the composition of building elements all of which are established early in the design phase with little building enclosure input in more traditional design processes.
- Although an integrated design process will not of itself result in improved project documentation, early involvement of specialist consultants may have indirect benefits. For example the building enclosure consultant can identify critical areas requiring greater or lesser degrees of attention prior to completion of the design documents.
- A collaborative process that brings all consultants together early in the design phase of the project increases interdisciplinary understanding. The potential for problems to arise in cases where the decisions and assumptions of one consultant affect the work of another is reduced. For example, assumptions made by the mechanical consultant with respect to air leakage characteristics of the building enclosure can often be incorrect and can lead to unacceptable interior environmental conditions which in turn create enclosure problems. If both consultants are participating in a process that sets goals and performance targets, misunderstanding can be avoided and both can work from the same design parameters.

CONCLUSIONS

Almost everyone involved in the construction industry, and many building owners are aware that failures occur in many buildings. A 2001 study reported in a CMHC research highlight[7], estimated the rate of premature wall and roof failures in Canada at 3 to 5% with an associated cost of $225 to $375 million per year. Recent experience in the coastal climate zone of BC has highlighted a range of durability issues relating to the building enclosure. Given that some level of failure occurs in all buildings, it is to be expected that unless specific measures are taken, green buildings are likely to suffer from the same range of durability and building enclosure problems that affect conventional buildings of the same type.

The issue that this paper addresses is whether or not an increased level of durability and building enclosure problems can be expected in green buildings, and whether this would result from the application of specific green building strategies. For this reason, when durability problems are identified in a green building it is important to fully understand into which category the problems fall. The Lemieux and Totten review of the Philip Merrill building clearly identified enclosure and durability deficiencies. The materials that were associated with the problems included engineered wood products, structural insulated panels, OSB, plywood and galvanized steel roofing and cladding. Although LEED points may have been acquired for the use of these materials, the materials themselves are conventional building products and are commonly used in non-green buildings. The specific problems encountered at the Philip Merrill building appear to result from poor detail design and construction and inappropriate material selection for the particular exposure conditions resulting from building form, and location, rather than specific green design strategies. The Merrill building case study illustrates that appropriate material selection and use is essential in all buildings and further that conventional performance criteria need to be considered in addition to green building criteria.

The review of LEED credits and associated design strategies indicated areas where there is increased potential for enclosure and durability problems. In many cases these problems are related to the use of innovative materials or technologies to achieve green ends. However the introduction of innovation is not unique to green buildings. Any situation where designers or contractors are unfamiliar with construction products or materials will result in greater potential for problems To the extent that designing and constructing green buildings requires the employment of new materials and technologies there will be an increased risk of durability and performance problems.

A review of many case study buildings indicates that while in some cases achieving LEED credits does involve material or technological innovation, in many other instances green design goals are achieved through more conventional means. Examples include the use of conventional materials that have recycled content, such as steel studs or rebar, and the use of local or regional materials. Additionally, it was clear that in many LEED buildings particular points are achieved for material or building characteristics that would be incorporated in a non-green building of the same type.

The degree of “greenness” or improvement in environmental performance of green buildings varies considerably. The first of the two case study buildings required 32 out of a possible 69 points in order to achieve a LEED ‘certified’ level. Inevitably when building designers and developers initially establish which credit areas to focus on to obtain points there will be a tendency to select the easiest points to achieve. In some cases it will be possible to achieve points without any significant changes to the building, for example points can be acquired for a building located in proximity to transit routes. This is not to suggest that there are not environmental benefits associated with these strategies, but rather that they do not result in any greater risk of durability or enclosure performance problems when compared to conventional buildings. In contrast when a building is designed to achieve a higher LEED rating there is less opportunity to be selective with respect to the credit areas in which points are achieved. These buildings will incorporate a wider range of green design strategies with an increased likelihood that some of the strategies involved will increase the level of risk of durability or performance problems.

Durability and building enclosure problems in buildings will often only become apparent after many years of service life. A major difficulty in investigating durability issues in relation to green buildings is that so many of the buildings are new and relatively untested. The performance of these buildings, and the degree to which they will experience durability problems, will only become apparent over time. For this reason, and to establish the effectiveness of green building strategies in reducing environmental impacts, on going monitoring and verification of performance will be required.

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[1] The Importance of Building Enclosure Commissioning for Sustainable Structures, D.J. Lemieux, AIA, P.E. Totten, P.E. Buildings IX Conference, Clearwater FL (DOE/ORNL/ASHRAE) 2004

[2] BedZed Housing Development, UK, in the Guardian, May 17, 2006. Seattle City Hall, Seattle Wa., Seattle Times, April 24, 2005.

[3] Leadership in Energy and Environmental Design Green Building Rating System, US Green Building Council.

[4] LEED Green Building Rating System, Reference Guide for New Construction and Major Renovations, LEED® Canada-NC Version 1.0, Canada Green Building Council, December 2004

[5] CSA S478-95 (R2110) Guideline on Durability in Buildings

[6] At the time of writing, application had been made to CaGBC. A decision was expected before the end of 2006.

[7] 2001 Building Failures Study, Research Highlights, technical Series 10-140, CMHC, 2001