Building Envelope Performance: What to Expect when You are Expecting

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ABSTRACT

The design and construction of new residential buildings is a complex process that involves a diverse community of stakeholders. The successful development of a building from concept to occupancy must include focus on the building envelope as an integral part of the process.

Each member of the stakeholder group has a diverse set of expectations and priorities for the building envelope which each feels should take precedence throughout the design, construction and ownership process. These expectations include issues related to operating conditions, technical feasibility, "constructibility", durability, initial construction cost, and life cycle cost.

Building envelope professionals who participate in building projects require an astute awareness of stakeholder perspectives. This can be a daunting balancing act considering the often competing interests of the various groups. The key is knowledge, risk management, communication and the authority to act.

This paper will discuss the different interests and expectations competing on a residential building project to promote a better understanding of the issues affecting the stakeholders and help all parties establish and achieve realistic and appropriate performance expectations.

This paper will present information obtained from members of the stakeholder community through interviews, on-the-job experiences, and a full-day education seminar prepared and presented on behalf of BCBEC and APEGBC in January 2004. The interpretations and opinions of the authors will form the underlying conclusions for the paper based upon their collective corporate experience working in this field.

INTRODUCTION

The design and construction of new residential buildings is a complex process, which involves a distinct community of stakeholders. The level of involvement of each stakeholder at varying stages of the building life cycle, coupled with the level of financial investment at that stage, creates perceived and actual risks which need to be carefully managed to ensure predictable and acceptable results. A sound risk management process must therefore be utilized in order for a successful project to reach its intended goals from concept through occupancy and final demolition.

All buildings are complex integrated systems with numerous components contributing towards an appropriate performance objective. One of the many component systems competing for attention during the building life cycle is the design, construction and maintenance of a suitable building envelope. The members of each stakeholder group have varying sets of expectations and priorities for the building envelope, which interweave with the other systems of the building. Each member is concerned that his priorities and risks are appropriately managed, which often leads to conflicts between competing objectives. Building envelope professionals who participate in successful building projects require an astute awareness of the unique perspectives of each member of the stakeholder group in order to ensure that this one component does not become "lost" in the creative jungle of design and construction. This can be a daunting balancing act considering the often competing interests of the various members.

The key is broad knowledge of the issues affecting a construction project, a proper risk management approach, open and honest communication, and the authority to make and enforce critical decisions.

The discourse over the causes for the recent "leaky condo crisis" in the Lower Mainland of British Columbia has seen substantial debate over the recent past. However, the common theme within this debate is a disconnect of knowledge, information and communication between stakeholders, with a resulting lack of understanding and respect for the issues and expectations of others.

In British Columbia, the Barrett Commission of Inquiry into the "leaky condo crisis" concluded that there were many issues that contributed to the collapse of quality construction in that province. Of these issues, the following conclusions generally relate to this disconnect among the various stakeholders [Barrett 1998]:

> *(i) an inability on the part of municipalities to effectively monitor building quality…;*
> *(ii) a lack of provincial monitoring to ensure accurate interpretation of the building code, as well as its performance requirements;*
> *(iii) a lack of developer, builder, and general contractor responsibility…;*
> *(iv) architects who have been unable to maintain professional responsibility…;*
> *(v) engineers who have been unable to ensure their involvement in the process will lead to quality construction of the building envelope;*
> …
> *(viii) a mortgage guarantee system which tends to serve the interests of the residential construction industry and financial institutions, without due regard to the consumer…;*
> …
> *(iv) a loss of collective memory, and lack of conventional wisdom, among inspectors, architects, engineers, developers, and contractors regarding the requirements for effective building; and*
> *(v) ineffective communication and transfer of knowledge…*

This problem is not limited to British Columbia, residential construction in general, or even Canada. Warner notes that 87% of respondents who commission building projects stated they received what they expected but this was not necessarily what they wanted [Warner 2001].

THE STAKEHOLDERS

Members of the stakeholder group for a building development and life cycle are discussed in the following sections, presenting a brief background, their involvement in the building in its life cycle and the authors' interpretations of their performance expectations for the building envelope. Where the various stakeholders have involvement in each of these stages has a direct impact on their performance expectation for each performance criteria, especially as these criteria manifest themselves with respect to the risks associated with failure.

The Developer

The developer initially has the largest stake in the project as the developer evaluates the costs of project development and construction against the anticipated sales revenue. Until the project is completed and sold, the developer carries the risk of significant financial loss. The more volatile the real estate market or construction industry, the greater the risk. If the demand for residential units is high, it is likely that a large number of units in the development will sell before the project is complete or possibly even before construction has started, even though selling prices are also high. While this may provide some security for the developer, if the cost of construction increases substantially, the financial viability of the project can be threatened. If residential housing demand is flat, there may be a problem selling all of the units, resulting in substantially greater financial risk.

These risks, as well as the fundamental desire to maximize profit, leads the developer to minimize the cost of the development; both soft costs (professional services) and hard costs (actual construction). Minimizing initial cost usually means; limiting design professional involvement (through lower fees), accelerating construction schedules, limiting material choices, and disregarding advice which is perceived to create higher initial cost with no corresponding perceived benefit.

For a developer-owner-operator, these initial costs are amortized over the entire life cycle of the building, since ongoing life cycle costs consisting of operational expenses, maintenance expenditures and renewals will often outweigh initial costs [Kirk and Alphonse 1995]. In the case of a residential condominium development, where the developer will not be the owner-operator and, therefore, has no ongoing financial interest other than near-term warranty liabilities, all costs must be amortized over the relatively short construction cycle. Cost implications are exacerbated by the perception that additional construction costs associated with greater performance can not be recovered through higher selling prices, especially if competing developments are not similarly constructed [BCBEC 2004].

The developer's time frame for project involvement will therefore frame his expectations. Typically, this translates into the building envelope performing without callback due to failure until the expiry of the warranty. Beyond that time, whether the various components that comprise the building envelope require frequent maintenance, premature renewals, or costly repairs to retain satisfactory performance, tends to have little impact on most residential developers.

The Design Architect

The architect is responsible for the overall design of the project and, as the prime consultant or coordinating registered professional, coordinating the activities of all other professionals that may be involved in the project. The design is conveyed through the project design documents, the adequacy of which have a significant impact on the quality of the building. Documents which are not sufficiently comprehensive will not enable the contractor to provide accurate or realistic pricing at the early stages of the project and can lead to an atmosphere of conflict during construction as all project team members struggle to identify and properly construct ill-defined assemblies and details.

The architect's involvement in the project may start from the very earliest feasibility studies, rezoning applications or development permit applications for the project. The architect will likely have little or no involvement in the project beyond the end of construction and occupancy, unless the architect is brought in by the developer during warranty issue resolution.

As the prime consultant the architect is responsible for the project's design and, therefore, its performance. However, "performance" must be defined both with respect to meeting the architect's client's expectations (the developer) as well as those of the end-user (the homeowner). Additionally, in a sharply cost competitive environment, the architect through experience and training will often place the overall form and aesthetic of the project at the top of the priority list, thus arriving at a design that may compromise technical functionality (or more accurately, reduces the probability of suitable performance) for the sake of visual appeal. Zoning requirements and municipal design panels, which impose additional and sometimes very restrictive requirements on the project, often further reinforces these priorities.

As a registered professional, the architect may have liability beyond the applicable provincial statute of limitations, extending over the life of the project. This professional responsibility and liability will create an implicit expectation that the project will perform as intended over its entire service life, given acceptable maintenance. Unfortunately, conflicts created by complex designs, fast-track design and construction, and divergent professional requirements, interfere with the architect's understanding of how "adequate performance" actually becomes manifested in the components and systems used for the project.

The Building Envelope Professional

Innovations in technology over the past century of construction have permitted the construction of buildings with less redundancy and lighter mass, allowing more economical construction but at the same time, creating structures more sensitive to the forces of nature and environmental loads. Additionally, society's demand for more efficient and appealing use of space has led to increased complexity in modern buildings.

The Building Envelope Professional (BEP) is a relatively new member of the project team in the evolution of construction, their existence necessitated by these building complexities and, in some cases, their resultant failures. For most multi-family residential projects in the Lower Mainland of British

Columbia, BEP designer professionals are now mandatory member of the design and construction team, required by several jurisdictions, and have a recognized separate contribution to the overall process [Kayll 2001]. Uniquely, this specialty draws from a wide variety of professionals including engineers of different disciplines and architects. The practice provided by this specialty is regulated by the respective professional associations [AIBC/APEGBC 1999].

BEP performance expectations are driven by a number of factors. The BEP is often called to investigate building envelope failures, determine causes, and make recommendations to correct problems. This has provided astute BEPs valuable feedback on what works and what does not, how various projects are designed and constructed, as well as an exposure to how the legal process interprets failures and assesses liabilities. While other stakeholders may be aware of such failures, they often lack the depth of exposure and knowledge, and direct involvement in failure investigation and repair, to avoid recurrence of similar problems. This experience will leave the BEP with perhaps the most realistic expectations of how the building envelope will perform, if not how it should perform.

The General Contractor / Construction Manager

The general contractor or construction manager is responsible for the actual construction of the project. For the purpose of this paper, this title will also include those sub-trades involved in the building envelope, and will collectively be referred to as the contractor. The type of contract utilized to deliver the project will greatly affect the priorities of the contractor. Guaranteed maximum upset price, stipulated price, and construction management contract agreements will affect how the contractor deals with the myriad of issues concerning the building envelope. Most contractors want to deliver a high-quality project. However, a contractor's value is usually measured by how quickly and economically the project is delivered within a loose interpretation of "quality construction". Quality construction is actually most often defined by the contractor, therefore placing the focus on speed and economic factors, which guide performance expectations.

Traditionally, the contractor is retained at the end of the design phase after the project is tendered or a price is negotiated. In this scenario, the contractor has little to no participation in the design process and can only provide input during construction when there is little scope change flexibility. In some circumstances, it is becoming more common for the contractor to be retained during the design phase, which enables the project to receive the benefits of the contractor's expertise. Time constraints and financing costs place immense pressure on the Contractor to meet schedules. This drive to move the project forward, even at the very early design stages is often counter-productive for the project. It is not uncommon for the contractor to be pricing or tendering portions of the work before some of the preliminary design is completed. This can lead to problems as various scopes of work and pricing are established on assumptions and past experience, yet conflict with the design and project requirements when they are subsequently finalized.

Similar to the developer and designers, the contractor's involvement is at the beginning of the project's life cycle, with possibly only limited participation in the project after occupancy responding to callbacks for repairs within the warranty period. The contractor's time frame for involvement in the project therefore establishes his expectations that the building envelope performs as the designers have intended with no callbacks until the expiry of the warranty.

The Authority Having Jurisdiction

Typically, the term "Authority Having Jurisdiction" refers to the national, provincial and municipal authorities, which regulate the building process. However, for this paper, the definition has been broadened to include government-mandated home warranty organizations, third-party warranty insurance providers, and professional liability insurers. None of these parties has an active part in the technical design or construction, yet they all have an indirect role by imposing requirements on various aspects of a project. Almost inevitably, these imposed requirements are focused on reducing risks of failure and, in the case of the private insurance corporations, minimizing the risk exposure during the term of the insurance coverage.

The involvement and influence of the authority having jurisdiction in the life cycle of the building is primarily centered on initial design, construction, and warranty/insurance coverage, and will have little bearing after occupancy except in the case of a failure or claim. The expectation is simply that the building envelope will meet applicable requirements and serve its intended purpose over its anticipated service life. For the government-mandated warranty organizations, it is expected that this time frame be, at least, somewhere in excess of the warranty period.

The Homeowner

The homeowner is the end-user and functionally has the largest stake in a project. The homeowner is responsible for the building over its entire service-life, including its operation, maintenance, renewals and associated costs. The homeowner is also obliged to the authority having jurisdiction to provide suitable levels of maintenance and repair to satisfy whatever legislated or warranty requirements exist. Ironically, the homeowners have the least input into how the project is designed or constructed and most likely have the least expertise related to the technical or financial operational requirements of the building.

Very soon after construction, and in many cases before construction is even complete in some areas of the project, the homeowners will become involved in the life cycle management of the building and will become its principal stakeholder. Often, the homeowner does not view his participation in the process in the same way or in the same context as the rest of the stakeholders. Whereas the other stakeholders speak of the building in professional terms, the homeowner identifies emotionally with the building as a "home".

For most homeowners the building envelope is an "out of site, out of mind" component. This would suggest that their expectations are that it will always provide protection from the elements and create a comfortable environment in which to live. Durability is similarly given little thought, with the assumption that little in the building will wear out or stop serving its intended purpose, except for items which are understood to have traditional life spans like roofs or weatherstripping. In many instances, these expectations may be unrealistic, as there is insufficient understanding of the technical aspects of the building envelope to allow for a more practical expectation of its performance.

This has been exacerbated historically by limited or non-existent information on the building envelope available to the homeowners when assuming control over the building. However, in some jurisdictions this trend is reversing. In areas where mandatory reserve fund studies and operating budget procedures are enforced by authorities having jurisdiction, homeowners are forced to come to terms with the performance of their building's components early in the building life cycle. In British Columbia, where reserve fund studies are not mandated, third-party warranty providers have enforced requirements for complete building envelope maintenance and renewals information to be provided to the homeowner. Finally, organizations like Canada Mortgage and Housing Corporation and the Homeowner Protection Office have been providing homeowners with information on the care and maintenance of the home.

PERFORMANCE CRITERIA AND EXPECTATIONS

All components of a building's construction carry inherent performance criteria as part of their inclusion in the design. These criteria vary significantly amongst various issues, depending upon whether the focus is on physical properties, intended impacts on use, support of the overall design intent, or other expectations.

For the purposes on this paper, we have selected a series of nine criteria that are most often impacted as part of design, construction and use as they relate to the particular intent for the building envelope components. In choosing these criteria, the authors have not attempted to provide an all-encompassing collection of all aspects, as this would lead to minute differentiation between issues on a scale inappropriate for the purpose of this paper. Instead, the intent is to provide broad criteria, which allow for broad interpretation between stakeholders.

In the experience of the authors, it is these broad interpretations that, in fact, lead to many of the problems and conflicts which arise in the traditional design and construction of a building. It is therefore critical for all members of the design and construction team to understand these criteria, and their

interpretations by the various stakeholders, in order to accommodate and achieve the most rational and collectively appropriate design for the end user, the homeowner. The following criteria are therefore the focus of this paper:

- Initial Cost
- Life Cycle Cost
- Aesthetic
- Thermal Control
- Vapour Control
- Rainwater Penetration Control
- Durability
- Maintenance Requirements
- "Constructibility"

The following sections outline definitions of these criteria as they relate to this paper and identify the key performance expectations and differences between the stakeholders for those criteria. It is important to understand that we have not attempted to prepare a comprehensive identification of the criteria or expectations but are instead focused upon the differences and impacts of these criteria on the building life cycle. We are looking at the impact they have on the process as seen by each stakeholder and not evaluating the importance of the criteria from a systems perspective.

Initial Cost

The Initial Cost criteria relates to the impact that the design and construction cost of the building envelope components have on the overall project [Kirk and Alphonse 1995]. For some stakeholders this is a key aspect and for others this has little or no impact.

It is important to separate this criterion from the next, life cycle cost, due to the tremendous impact that initial cost maintains over the entire process. Many decisions are made based on initial cost and it is important for all stakeholders to understand how these decisions affect overall performance.

Initial cost is most important to the developer and the contractor, for self-explanatory reasons. Much of the pressure on the design process results from the need to either; keep costs low enough to enable the developer to meet a development budget, or prevent cost escalation in a fixed price contract to enable the contractor to stay within his budget. Given a fixed development cost budget, a developer would much rather spend available budget on "saleable" items like higher-end finishes than on items "invisible" to the market. A developer is only willing to spend money on "real" short-term risk reduction measures [BCBEC 2004].

On the opposite end of the scale, the insurance industry and authorities having jurisdiction have little concern regarding the initial cost of the building envelope other than the use of the construction and/or design fee amounts as baseline references for development fees or premiums.

The architect is concerned about system initial costs only as they reflect on the overall development concept and the architect's commitment to the developer. In our experience, the architect has a limited concern for building envelope initial cost considering the envelope components' relatively limited impact on the overall budget. The BEP has similar perspectives to the architect although more focused upon the envelope components. BEPs tend to be more concerned with technical suitability than with initial cost.

The homeowner has a passive interest in the initial cost only as it affects the overall purchase price of his portion of the building, if at all. Since market forces tend to set real estate prices, there is little direct relationship. This impact changes dramatically when the homeowner becomes a form of "developer" when conducting repairs and renovations to the envelope. However, in these rehabilitation cases, the homeowner has to balance the sometimes-competing issues of initial cost against life cycle cost.

There is often disagreement amongst the stakeholders during construction over decisions as they relate to initial cost and perceived impact on other criteria. While performance expectations are often loosely

defined qualitatively or in terms of opinion of probable performance, initial cost is known quantitatively, thereby creating a "what is known versus what is unknown" conflict.

Life Cycle Cost

Included in life cycle cost analyses are cost implications related to initial cost, maintenance costs, recapitalization costs (renewals), expected and historically proven durability, disposal, etc. [Kirk and Alphonse 1995]. Another aspect that is gaining favour in the current climate of sustainable design is the cost associated with embodied energy effects. The costs associated with the use of energy to extract, manufacture, transport, install and dispose of each of the components of the building envelope system are starting to be fed into the life cycle cost equation as an environmental cost.

Homeowners have a strong desire to see proper life cycle costing applied to building envelope components due to their long-term involvement with the building. However, most homeowners are relatively unsophisticated in the concepts surrounding the building envelope function and therefore do not understand its importance until the first time they see failures or the requirements for recapitalization investment. Homeowners assume that the rest of the stakeholder group will provide proper attention to this criterion.

Building envelope professionals have a mid-range interest in seeing proper life cycle concepts applied to the design of the envelope. This is largely due to more extensive involvement in the repair of failed systems rather than the original design and construction stages. This interest does vary significantly depending upon the jurisdiction in which the BEP is involved, with the interest being higher in regions with mandated attention to longer-term warranty provisions and/or mandated participation in the design stage.

Life cycle cost performance has very little impact on the other stakeholders, due primarily to their limited involvement with the long-term operation of the building.

Aesthetic

Aesthetic criteria are a function of the impact building envelope design choices has on the overall form of the building and its character. Decisions on visible details and components of the envelope as well as perceived appearance can sometimes cause conflict with better envelope performance. How the building envelope components affect the "language" of the architecture and the overall attractiveness of the building has direct impact on the expectations of some stakeholders.

Homeowners and architects both place a high importance on the overall appearance of a building when it comes to making decisions related to the building envelope. For homeowners this is often due to; i) the emotional nature of a home buying decision, and ii) an unconscious assumption that the more technical characteristics will be managed directly as part of professional responsibility for performance, leaving the decision as to whether a design is attractive or not up to the individual. For architects, these decisions are rooted in the underlying design culture, where expression and beauty carry a high value, especially when generally compared to the engineering profession, in which form traditionally follows function.

Developers are interested in the aesthetic quality of a building as it contributes to the perceived market value and as elements of their collective portfolio. Often, a developer will defer to the architect's expertise in these matters, but in many cases a developer will have a signature style, which is replicated throughout various projects.

In some instances, BEPs tend to ignore the very real impact technical envelope design decisions have on the overall building aesthetic, sometimes to their discredit. Many engineers not trained or experienced in appreciating the value of a design's form and appearance often do not recognize the negative impact choices made for technical reasons only have on the aesthetic of a building, especially during rehabilitation projects.

The authorities having jurisdiction have a fleeting interest in ensuring that the building meets with the objectives of the municipal zoning and design guidelines. Since aesthetic decisions can have an important impact on envelope performance, careful attention must be paid to this criterion.

Durability

Durability is a broad criteria which can range from being able to survive the construction process to being able to resist a higher than code-minimum climatic load. The authors have defined durability as "the ability to function as intended through the expected life of the building". Definitions of "intended function" and "expected life" vary between stakeholders and therefore influence their performance expectations. The intent in this paper is to leave the definition of durability broad to allow the various interpretations by stakeholders to influence the perceived level of importance. It is critical that the influence of accepted durability concepts, like CSA S478 *Guideline on Durability in Buildings*, be integrated with the more general decisions taken as part of any design.

Data on the durability of building components is often difficult to obtain and can provide wide ranges of expected life time frames. Information in the form of accelerated weathering tests is sometimes available; however, that information often does not directly correlate to performance standards and, while useful in determining relative durability of similarly tested components, has limited applicability. Durability of installed and constructed systems and assemblies is more difficult yet to establish until collective experience can be brought into play. The loss of collective memory noted in the Barrett Commission report [Barrett 1998] indicates the additional conflict, which is brought to bear on this issue. Additionally, it must be pointed out that given the pace of modern development, the lessons from failures (inadequate durability) are often not learned quickly enough to prevent further failures from occurring.

Architects and BEPs see durability as a key performance criteria for the building envelope due largely to the desire to provide quality, lasting buildings. For this criterion, the architect tends to have a broader view due to the more traditional context, which this design professional maintains over the entire building design. BEPs have a more focused perspective, as they tend to concentrate on this one building system.

Developers and authorities having jurisdiction tend to view durability in a general form, with concern focused mainly on overall building presence and interaction with the urban fabric. Specific durability issues related to building envelope performance do not tend to be considered and do not represent actual or perceived risk to these stakeholders. The insurance and warranty industry are only concerned with durability as it impacts the duration of their involvement with the building, which tends to be a relatively short timeframe when compared to the overall building life cycle.

Homeowners want their building to last and they want it to perform as intended with the least impact and least input possible. The issue gains more importance when components fail prematurely, and the tendency at that time is to look at systems with perceived greater durability. Evidence of this trend, as guided by the real estate market in the Lower Mainland of British Columbia, is the proclivity towards advertised "concrete construction" in residential development. Concrete structural design is perceived to be more durable than wood and steel as a result of the widespread failures of multi-unit residential buildings in this jurisdiction in the 1990's.

Maintenance Requirements

Maintenance as a performance criterion varies in importance significantly between various stakeholders due to the direct impact (or lack thereof) maintenance quantity and success has on the performance of the building envelope as a system. Rating the importance of this criterion is also a direct function of the level of understanding of the stakeholder of this factor. Maintenance issues such as cost and ease have implied related functions.

Interestingly, most stakeholders will rate their performance expectation for maintenance as relatively low. This may be due to a variety of issues but is most closely linked to the risks assumed by each stakeholder should proper maintenance *not* be conducted.

Developers, contractors and the authorities having jurisdiction have little or no involvement with the maintenance aspects of a building's life cycle and therefore do not assign much importance to this function. The insurance industry has some interest but this is usually limited to the duration of the specific coverage provided, which tends to be relatively short over the total building life cycle.

The design community carries some professional obligation to ensuring attention is paid to this function, as there is a benefit to society as a whole in limiting the premature building failure.

Homeowners will see maintenance as an important continuous obligation where cost will be an important component. Expectations are that maintenance will be uncomplicated, affordable, easy to manage and reasonably consistent with historical experience.

"Constructibility"

The underlying intent of this criterion is best stated as "How easy is it to construct the components of the building envelope?" This criterion has a somewhat limited importance amongst the various stakeholders but it is a critical component of the overall process. This criterion is often overlooked until the project gets to the construction phase, which can lead to conflict between the various parties. Analysis of failures [CMHC 1998][Derome and Siva Rivera 2003] shows the common construction related failures are either:

- Poor construction due to a lack of understanding of the intent of the design components, or
- Poor design forcing poor construction

When evaluating the level of importance assigned to this criterion by the various stakeholders, there are two main aspects, which come into play:

1. How easily can this design be built by the available work force?
2. How much will it cost to build?

Constructibility issues have little to no importance to the homeowner, authority having jurisdiction or insurance and warranty industries. These stakeholders do not have a vested interest in whether a concept can be built since their various risk related issues are not realized until the building is completed. These stakeholders are simply interested in the fact that the building is built (to an acceptable minimum standard) and often assume it must have been performed correctly.

Since the developer and contractor fundamentally finance the construction of a building, they take all of the risk until it is complete and therefore are keenly interested in easy-to-construct building envelopes. Contractors have the most interest in this criterion as they are tasked with the construction. Any design, which is not constructible, is a liability and a hindrance to the delivery of the project on budget and on schedule.

The ability to construct a properly functioning envelope is important for the design professional since there is an expectation of adequate performance once the project is complete, and the probability of achieving this performance is greater if a system is better understood and more easily built by the contractor. Assembly sequencing often has a direct impact on the success of the design. New or unusual systems carry a greater risk of mistakes and therefore failure.

Technical Criteria

Technical performance requirements for the building envelope are described in the various applicable building codes and associated standards. Notably, the National Building Code of Canada (NBC), Part 5 provides performance-based objectives for building envelope design, leaving interpretation and integration of these technical criteria with the non-technical criteria up to the design and construction team. Other Canadian jurisdictions most often adopt the NBC as the applicable code, with changes to suit local conditions as appropriate. Nevertheless, the underlying building physics which govern performance are the same and should ultimately govern good performance choices during design, construction and ownership.

The next three criteria relate to physical performance aspects of the building envelope as commonly defined within the various codes and standards. These criteria are separated to allow for a review of how each has a measurable impact on decision making.

A. Thermal Control

The ability of the building envelope to manage thermal comfort has an impact on actual and perceived value and performance. Decisions made on achieving thermal comfort often have significant impacts on all stages of the building process and each stakeholder will have varying perspectives on this criterion. This criterion is technical in nature although performance is often perceived and measured qualitatively.

Thermal control is a function of two components:

- Control over the transfer of heat energy (indoor comfort)
- Control of air movement as it affects both occupants (drafts) and building components (condensation related damage)

The homeowners have high expectations for good thermal comfort primarily due to the long-term use of the facility over its life cycle. Homeowners expect appropriate decisions have been made in conjunction with the anticipated climate loads and expected industry standards for the maintenance of reasonable heating/cooling bills and for a comfortable home. They also expect that appropriate decisions be made to prevent damage to components due to condensation or other heat-related effects.

Architects and BEPs also have a strong preference for appropriate performance as this (and the following two) criteria form underlying building blocks for their professions. In jurisdictions where BEPs are mandated as part of the design and construction of buildings, architects have tended to reduce their involvement as they rely more heavily on the abilities of the BEP.

A developer's and authority having jurisdiction's desire for proper thermal comfort performance relates fundamentally to ensuring that minimum codified standards are met and ensuring the building obtains its market value.

In our experience, the insurance industry and contractors have little interest in this criterion, as it does not create significant risk to their operations.

B. Vapour Control

Like thermal control, vapour control is a technical performance objective. Unlike thermal control, vapour control is only important to most stakeholders when it is not properly executed, causing subsequent damage.

Vapour management is a function of:

- condensation control (both vapour diffusion and air movement)
- indoor comfort (relative humidity and moisture content)

Various system functions and design decisions directly impact these two aspects. Stakeholder interest in these functions varies depending upon where the stakeholder fits into the building life cycle.

Expectations for performance are similar to thermal control, although much greater value is attached to this function only when failures in system performance have occurred. There has been growing evidence of these failures in warmer, humid climates due to misapplication of design concepts developed in northern climates and a poor understanding of building physics and actual climate loads.

Vapor control is one of the issues, which does garner a fair amount of attention within the design professional community, both in terms of material selection, construction requirements, and HVAC design.

C. Precipitation Control

Control over precipitation is a fundamental criterion for the building envelope, and has been so from humankind's earliest origins. The use of original shelters like caves was intended to control exposures to rain, snow and sun. Thermal and air quality comforts were augmented functions separated from the envelope.

Nevertheless, liquid water sourced from the exterior continues to be a primary cause of building failures. While some may argue that this is simply a function of the cycles of nature, those involved with the building industry are constantly looking to manage the impact of this criterion effectively.

The importance of proper management of climate precipitation loads, including rain and snow, is therefore a given in an isolated assessment. However, when this issue is coupled with decisions related to the other criteria, the relative importance often becomes less clear. Expectations as defined by stakeholders therefore are important to understand as the process progresses.

Homeowners have a life-long expectation for good performance of precipitation control measures. They also have a better understanding of the impact of good maintenance and capital replacements on this criterion. Likewise, homeowners have very low tolerance for failure of these functions.

Architects and BEPs have keen interest in maintaining good precipitation control performance. Stimuli for this desire ranges from ethical standards of care through to concerns of professional reputation. The increased attention caused by significant rainwater penetration failures in regions like British Columbia, Quebec, the U.S. Pacific Northwest and North Carolina has also increased pressures from the insurance and warranty industries.

The conflicts arise when trade-offs between precipitation management and initial cost are made.

SUMMARY COMPARISONS BETWEEN STAKEHOLDERS

There are strong correlations in performance expectation between the homeowner as end-user and the design professionals; be they architect or BEP. This is fundamentally a rational observation as the design professional is, in effect, the homeowner's technical representative through the design and construction process. Most often, conflicts arise between these two groups when the realities of the process do not meet the expectations of the Homeowner, especially when the design professional must trade better performance for rational risk management.

There is a strong disconnect between the performance expectations of the homeowner and the development community, which can be directly attributed to the clear separation between each stakeholder's involvement on the building life cycle. Fundamentally, the two only meet at the handover stage. Yet each has a significant financial investment in the process, with the resulting risk. The design professionals are often tasked with mediating these two disparate levels of performance, thus requiring an important element of professional responsibility and ethical standards.

Similarly, there are significant differences between the developers and the design community, due primarily to the very different roles each plays in the construction of the building.

The insurance industry has a very focused set of performance objectives, as does the contracting community. These focused objectives are directly linked to the limited functional involvement each has in the overall building life cycle. The risks managed by each stakeholder are significant to that stakeholder and must be acknowledged and appropriately managed in the process. It is therefore important for these risk issues to be placed in the proper context of the overall equation. Balancing this perspective with the expectations of other stakeholders is a fundamental duty of the design professional.

The authorities having jurisdiction have a relatively lesser role to play in the overall definition of performance expectations once the applicable codes and standards have been defined. This is largely due to

the very limited real risk tied to their involvement. Homeowners do expect a minimum level of quality and attention be paid to these issues as a means of providing an "unbiased" referee for acceptable performance.

CONCLUSIONS

Building envelope professionals who participate in successful building projects require an astute awareness of the perspectives of the stakeholder group. This can be a daunting balancing act considering the often-competing interests of the various members. The key is knowledge, proper risk management, honest communication, and the authority to make and enforce reasonable decisions. From the above discussion on stakeholder expectations, it is clear to see that each aspect of the design and construction process is fraught with conflicts built into the process. It is the proper identification and subsequent management of these conflicts that separates good outcomes from bad.

As with all relationships, the key is communication. Good, effective communication requires certain actions by each stakeholder as a member of the building design, construction and operation team. It is recommended that "open communication" itself be clearly communicated to all project participants at the start of the project as an objective with the following key attributes identified and adopted to achieve that goal:

- Honestly identify one's own perspective and effectively communicate that perspective.
- Listen to others' perspectives and incorporate them into the decision-making process.
- Weigh benefits against costs in a factual and unbiased manner.
- Accurately identify all risks, without under-estimating or over-estimating their consequences.

Building envelope professionals are essentially risk managers and must enter into all design and construction scenarios fully informed of all potential risks inherent in the building envelope, and the implications of those risks for the various stakeholders. To be a good risk manager, the building envelope professional must possess an extensive knowledge not only of the technical aspects of the profession, but also an awareness of the expectations of all stakeholders.

Good communication is a function of each stakeholder's point of view being taken seriously. When a building is being designed and built, this can only rationally be achieved when the stakeholders are members of the team from the beginning. If the building envelope professional is included in the design process early enough, the BEP will be able to be a more effective team member, able to more significantly influence the design, instead of only commenting on what has already been decided. Similarly, if the contractor is included as a member of the design team, and not simply charged with building the project as quickly and economically as possible, his expertise can be utilized and incorporated in the design. The real benefits with this scenario are not actually technical, but psychological. Involved in the process from the beginning, there is a far greater likelihood of an atmosphere of trust, understanding and cooperation developing, instead of conflict.

We believe that the key aspect of successful design and construction is the integrated design process. While this terminology has recently become a new topic in the industry with the advent of the "green" sustainability process, it is in fact a re-affirmation of what were considered traditional good design practices of the past [BC Building Projects Committee 2004]. Both authors for this paper have been involved in versions of the design and construction process, which worked well, and versions, which did not work well. The situations, which have worked well, were always accompanied by early and trusted involvement of the stakeholders in the design process, where decisions on design integration could be made in an integrated fashion.

As part of the research for this paper, the authors have noted that there is consistent mention of the lack of commissioning and post occupancy evaluations (POE) of constructed buildings, which is consistent with the authors' experiences. Without some type of feedback loop, there is no formal method for stakeholders directly involved in the design and construction process to evaluate and modify future decisions based on actual, and not perceived performance of past projects. A structured POE process would also greatly decrease the time the construction industry requires to identify and implement any required changes. Until

such time as POE procedures are integrated into the construction process, there will be no reliable and efficient way for all stakeholders to evaluate their performance expectations for the building envelope and measure the effectiveness of existing designs and construction to meet them.

The authority to make and enforce decisions is not a function bestowed upon most specialized building envelope professionals. The City of Vancouver and a few other municipalities in the Lower Mainland of British Columbia have adopted a requirement for formal BEP involvement in the design and construction of the building envelope on most new and rehabilitated residential buildings. This recent involvement has dramatically changed the emphasis on the building envelope. A significant component of this increased emphasis is the BEP's direct responsibility for the building envelope and therefore the duty to enforce related decisions. Signing authority for completion of construction projects has granted the BEP the ability to manage and control more aspects of the envelope. This has also placed greater responsibility on the BEP to make prudent decisions, balancing the interests of all other stakeholders. The authors believe that this model has contributed to a marked improvement in the quality of construction for these buildings and this model should be studied and adopted in other jurisdictions across North America.

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