Green Assessment Tools: The Integration of Building Envelope Durability

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Abstract

There has been a recent trend in the North American building market towards green buildings. This trend has resulted in the development and increased popularity of several green building assessment tools, including LEED™, Green Globes™, Built Green™, and GBTool. The tools attempt to measure the "greenness" of a project, typically by awarding points or credits for achieving certain prescriptive or performance based requirements. However, to allow adaptability and flexibility within the tools, there are a great number of variables, ranging from natural light infiltration, location of material manufacturing, to the site selection. In most projects, the selection of credits or points is predetermined by the building use, given site, geographic area, project cost restrictions and determined rating level. For this reason, assessment tools have come under a considerable amount of criticism. Ultimately, the tools attempted to provide a means in which to compare fundamentally different building traits, and in the end provide a numerical value to compare with other green buildings.

The majority of green building assessment systems focus on the design to the constructed building, with little focus on the effect of the building system's life during operation. This tendency has resulted in a failure of many rating systems to properly consider durability, lifecycle cost, and the effects of premature building envelope failures.

This paper will discuss green building assessment tools, their prime focus areas, the importance of designing for durability, and a proposed basis for evaluating durability. It also includes a review of four Canadian green assessment tools, the degree to which these systems include durability of the building envelope, and suggestions for future improvements.

INTRODUCTION

In the last ten years there has been a growing interest in green buildings and green materials, and a general movement towards a more sustainability built environment. The media has played an important role in this movement. It seems that everyday the newspapers, radio or television reminds us that our resources are limited, shrinking fast and a source of much of the global unrest. The general public has been gradually beginning to accept that the current ways of using our resources is unsustainable.

As the public has become more aware of environmental issues, they have also been inundated by marketers claiming that their products and buildings are green, sustainable and environmental. This emerging interest required the need to define greenness, and minimize "green washing" - the marketing statement without environmental substance. These are some reasons why assessment tools were created and promoted in the building industry.

In the early 2000's the United States Green Building Council (USGBC) released their assessment tool Leadership in Energy and Environmental Design (LEED). LEED was blessed with good timing in the market and incredible support from the United States government, the AIA (American Institute of Architects), and similar environmental stakeholders. Since its creation it has had exponential growth, not only in the United States, but worldwide. LEED captured and to some degree created today's market on sustainable design and green buildings. Following LEED, more and more tools emerged to capitalize on the growing green market, using LEED as the new base model.

As outlined in the USGBC literature, the LEED rating tool was created to:

- Define "green building" by establishing a common standard of measurement
- Promote integrated, whole-building design practices
- Recognize environmental leadership in the building industry
- Stimulate green competition
- Raise consumer awareness of green building benefits
- Transform the building market

To understand assessment tools, we need to understand why they were created and what they focused on. The following outlines a brief history of green assessment tool development and recent criticisms.

History of Green Assessment Tools

Assessment tools were primarily developed to assess, or measure specific aspects of a building, pertaining to sustainability goals. Once measured, buildings could be more easily compared with current and past building practices and other green buildings. The focus areas were chosen to address key waste streams and inefficiencies in buildings and the affects on the end users. Most tools focused on three main areas; energy, water and material use in buildings. Each area is typically evaluated on its net use—if the building produces or reuses resources, its efficiencies, and its percentage of reused, recycled or virgin materials. A common indictor used in sustainable design is embodied energy use. Embodied energy is the amount of energy consumed in the extraction, manufacture, transport, construction and assembly on site of building materials. It can also include the energy costs of disposal of waste or surplus materials.

To develop the green assessment tools, the authors used existing sustainable practices, such as increased daylighting, operable windows, and native plants; improved efficiencies (energy and water use), monitoring and commissioning; and promoted biodiversity, material reuse, recycling, and urban infill or densification. The authors' were typically groups of individuals with varying backgrounds and opinions, which provided a holistic approach to building design. The content of the tools would have also been influenced by political and corporate interest (e.g., incentives or interested directions), and environmental trends (e.g., recycling, oil crises).

Although environmental assessment tools existed earlier than ten years ago, they were typically used by academics to study buildings and their effect on the environment. Design professionals did not commonly use them. Two tools worth mentioning are the UK BREEAM model (British Research Establishment's Environmental Assessment Method) and the Green Building Challenge process (GBTool). These are considered by many as the birthplace of environmental assessment tools. Many of today's tools are based upon or were influenced by BREEAM and GBTool. The GBTool process was actually designed to allow users to focus on regional priorities, technologies, building traditions and cultural values in order to modify or create their own assessment tool. It was never intended to be directly applied by the user, nor to be applied to commercial use.

Green assessment tools were never designed to be foolproof or all encompassing. They were required to be specific enough to be relevant, and general enough to be transferable to various building types. As well, the tools needed to be easy and inexpensive to use. Ultimately, the tools attempted to provide a process in which to compare fundamentally different building traits, and in the end provide a numerical value to compare with other assessed buildings.

As outlined above, LEED, as well as similar tools, were created to; define green buildings, promote integration, recognize leaders, stimulate competition, raise awareness and transform the market. Although criticisms have been made about the use of the tools, for example “point shopping” (designing for points or credits rather than for the good of the building), or application cost, but few criticisms are about why it was created. Clearly, LEED has achieved its goals of raising awareness and transforming the market.

Another criticism that has been raised concerns the fact that the majority of green building rating systems were designed for new construction, and hence have focused on the design of the constructed building. Although energy, water and occupant comfort were well covered in the tools, there was little focus on the effect of the building system’s life during operation. This is especially true for envelope performance. This tendency has resulted in the failure of many rating systems to properly consider durability, lifecycle cost, and the effects of premature building envelope failures. One high profile example is a LEED Platinum certified project in Maryland. The project, which was heralded as a model of sustainability, was plagued with water ingress and material deterioration within years of occupancy.

Certainly the affects of building durability and life cycle performance cannot be overlooked in assessing green buildings. The problem has been defining durability and finding a method of integrating and assigning the relevant importance to building durability.

Durability in Sustainable Design

Currently, assessment tools have been looking at ways to implement the principles of durability, and life cycle assessment. These new focus areas are critical, as premature deterioration of buildings and building components has become an increasing problem in new and existing buildings. The cost for repetitive maintenance, repairs, premature replacement, potential health effects and occupant disruption of use has escalated to multibillion-dollar levels. The repairs have resulted in increased embodied energy, which over the expected lifetime of the building can far outweigh that of the originally constructed building. This has obvious impacts on the sustainability of the building industry.

As there is often confusion about technical terms, as they have been adapted in common day language, it is important to clarify three specific definitions.

Sustainability

Sustainability is a concept that relates the continuity of economic, social and environmental aspects of human society and non-human environment.* As defined in the 1987 Brundtland Report, sustainable development is development that "meets the needs of the present generation without compromising the ability of future generations to meet their needs".

Durability

The term durability is commonly used in today's language, especially in marketing, to refer to materials as being strong, tough, long lasting, etc. Durability as defined in the Canadian Standards Association (CSA) Standard S478-95 (R2001) *Guideline on Durability in Buildings*, is the ability of a building or any of its components to perform its required functions in its service environment over a period of time without unforeseen cost for maintenance or repair. The important aspects of this definition are the words "required function", "service environment", and "period of time". By this definition, durability is not solely a material property, but a function of material within a given environment. This is a common misunderstanding.

Service Life

Service life is generally described as the actual time during which the building or any of its components performs without unforeseen costs or disruption for maintenance and repair. It is also important to understand the difference between "designed" service life and "predicted" service life. Designed service life is the service life specified by the designer in accordance with the expectations (or requirements) of the owners of the building. While predicted service life is the service life forecast from recorded performance, previous experience, tests or modeling. Each has its intended function in the design and construction of a project.

The link between all of these terms is that of service life. If building are to be sustainable, they will need to last for their intended service life, which should be as long as possible to minimize resource use and waste. Complications in this theory arise when a building is designed, for specific markets or other reasons, as a temporary structure. So, how best should durability be assessed for use in sustainable design?

In researching methods to assess durability we found several references in building codes, in countries such as Australia, Canada, and Hong Kong, and in two well known standards (International Standards Organization (ISO) 15686 and CSA S478-95 (2001)). The reviewed building codes, bulletins and guidelines illustrated similarities for defining durable buildings, with specific focus on the building envelope. A common focus was on material performance and compliance to specific, regional or international standards, with references to the less tangible factors, such as environmental conditions and design detailing.

It could be argued that one method to define and assess durability would be to use a performance compliance approach; similar to most building codes. This would rely heavily on the content of the project specifications, and less on the project drawings or details. The specification would require materials to comply with well documented standards, which address the performance requirements for typical assemblies, including curtainwall, pre-cast concrete, and engineered cladding assemblies. The compliance approach puts the responsibility on the designers to appropriately transfer the intent of drawings and details into specification language (e.g., appropriate standards to follow, materials to select and installation instructions), and the manufacturer/contractor to supply and install materials per the specifications. Unfortunately, materials alone do not build a durable building. The specifications, as they are designed, divide materials up into separate divisions making it very difficult to review the impact of material choice and changes (e.g., alternatives that occur in the tender or "value engineering" stages) on the end constructed product. The reliance on specifications is not a sufficient way to ensure building durability.

The ISO 15686 and CSA S478-95 standards recommend a process for defining and determining building durability or service life. In essence, the standards suggest that to properly assess durability, one needs to first establish a basis for evaluating durability. This can be done by establishing a series of service life benchmarks; one for the building as a whole and then one for each major component. The benchmarks are not intended to be exact, fixed numbers. They are required to make decisions, hence need to be approximate numbers or tight ranges, such that they can be compared, reevaluated and adjusted. Once the benchmarks are established, each element of the building can then be compared back to the benchmark. An element that is significantly higher than the benchmark needs to consider reuse in the future. An element that is significantly less than the benchmark needs to consider future replacement. Determining the predicted service life of materials is a more complicated matter and requires specific knowledge of building science and material properties.

The following outlines one proposed method to assess building durability throughout the design and construction process. The method builds upon principles outlined in the ISO and CSA standards.

- **Schematic Design Phase** – establish the building's function and service life.
- **Design Development Phase** – establish preliminary service lives for the structure and cladding/roofing assemblies. Typically structure would be equal to building service life and cladding elements would be relative to structure (e.g., equal to structure, ½ life, etc.). Considerations include:
    - Life cycle Analysis and Life cycle cost
    - Initial building budget and Operating budget
- **Construction Document Phase** – select materials to reflect the preliminary service lives and consider:
    - Environmental conditions that affect the building, including both exterior (i.e., wind, exposure, rain, and snow/ice), and interior (i.e., freezers, pools, archives)
    - Maintenance difficulty, including, access, cost and frequency
    - Result of failure on building occupants (e.g., safety, health, loss of operation)
    - Detailing of assemblies and assembly interfaces, that allow easy replacement and renewal
    - Ease and method of component or assembly replacement, including construction demonstration and/or method outlined on shop drawings
    - Best practice design principles and historical performance
- **Tender and Pre-Construction Phase** – reevaluate the service lives established throughout the design development and construction document phases. This phase presents a major hurdle for building durability, due to the quick process, cost evaluation (value engineering) and multitude of alternate materials proposed.
- **Construction Phase** – establish quality control and assurance protocols (envelope commissioning), including mock-ups, performance testing and field review. Consider building's service life when issuing site instructions and changes to design.
- **Post Construction Phase** – evaluate assemblies for performance and address deficiencies.

The above outlines one method or framework to assess building durability, but does not represent an exhaustive list of all issues that require attention. The above method should be used as a starting point to develop a project specific durability plan. The most important aspect is that a method be developed and used early and through the project life. A plan established too late or an early plan that is never used will not achieve the goal. Project teams may find it useful to assign key individuals to evaluate and reestablish durability objectives throughout the project.

The proposed method has been used as a basis to review the following green assessment tools and their aspects of durability.

REVIEW OF ASSESSMENT TOOLS

Four green assessment tools were selected for this review. They were chosen for their historical importance as development tools (GBTool and Green Globes), market leadership (LEED Canada) and current adaptations for residential low-rise buildings. All the tools are currently used, in some fashion, in the Canadian building industry.

GBTool

GBTool is a building environmental assessment tool developed in an international collaborative effort during the Green Building Challenge (GBC). GBTool has undergone several changes and refinements since 1998, including a 2005 version used to assess buildings at the Sustainable Building 05 Conference in Japan. This paper reviewed the GBTool 2002 guideline and GBTool 2005 assessment worksheet. The GBT05 categories were restructured to allow comparison with the LEED and Green Globes assessment tools.

The assessment areas in GBTool are divided into general "Performance issues", and then further divided into "Performance Categories", which collectively assess the building's performance. The scoring can range from negative to positive points. Negative points are given for unsatisfactory performance, zero points for standard practices, and up to 5 points for demanding performance. The following categories sections highlight aspects of durability in the building envelope.

> ***Control of moisture in the building*** assesses the design measures taken to minimize moisture build-up within the building envelope. The performance measure is defined by design features that consider water leakage, moisture migration, condensation, and incorporation of systems, such as rainscreen and drainage cavities. The section also suggests that consideration should be given to building envelope detailing and wall sections illustrating the air and vapour barriers. Service life is also discussed in reference to the air barrier. It states "*The design of the total air barrier assembly…have a service life as long as the life of the building or, at a minimum, be located such that it may be serviced as necessary*."
>
> ***Maintenance of Performance*** discusses the importance of designing for maintenance and replacements. One category under this section, ***Protection of materials from destructive elements***, assesses the materials that make-up the building envelope and their appropriateness for their intended environment. It states, "*The potential life-span of major components such as structure and building envelope will, to a large extent, result from the durability of its constituent materials, components, assemblies and connections between them. If service loadings are not exceeded, durability in this case depends largely on*

exposure to climatic and other environmental stresses." Under the performance measure, it states, "*assessment should be based on details roof and wall sections, and other critical aspects such as roof overhangs showing that effective measures have been incorporated to limit water entry and migration of moisture (e.g., continuity of air/vapour barrier, exterior detailing weather membranes etc.)*"

Development of construction process quality control measures discusses the merits of quality control during construction to meet the design intentions. The performance measure is based on the number, type and effectiveness of measures to ensure quality control during construction.

Appointment of commissioning agent and development of commissioning protocols recommends testing the air-tightness of the building envelope in areas with high differentials between exterior and interior temperatures.

The GBTool protocol outlines some of the major issues outlined in this paper's proposed method to assess durability, including design, maintenance and commissioning. Although the protocol does not discuss the importance of establishing the design service life of the building, it does reference relative service life as an important aspect in selecting materials.

Green Building Initiative (GBI) Green Globes™

In 2000, BREEAM Green Leaf™ became an online assessment and rating tool under the name Green Globes™. In 2004, the Building Owners and Manufacturers Association of Canada (BOMA) adopted Green Globes™ for Existing Buildings under the name Go Green Comprehensive (now known as Go Green Plus). This paper discusses the Green Globes™ v.1 Rating System for new construction, to allow comparison with GBTool, LEED™ and Built Green™.

The Green Globes™ system is a questionnaire-driven tool. At each stage of the design process, users are asked questions that guide their next steps and provide guidance for integrating important elements of sustainability. The questionnaire is the basis for the rating system. There are 1000 points available in seven areas of assessment. The buildings rating (1 to 5) is based on a percentage of the total points achieved. The following outlines aspects of building envelope durability discussed in the Green Globes design summary.

The objective of Section C2, ***Reduce Energy Demand – Building Envelope***, is to minimize energy lost or gained through the envelope and prevent moisture damage. The requirements of this assessment area is to meet the Model National Energy Code for Buildings (MNECB) for thermal resistance, and design to prevent water ingress (ground or rain) and implement best practices for air and vapour barriers (including detailing, mock-ups, field review and testing).

One objective of Section E.1, ***Low Impact Systems & Materials***, is to choose envelope assembly materials (cladding, windows, etc.) with the lowest embodied energy and life cycle environmental burden. Materials are to be evaluated through LCA tools, such as Athena and BEES (Building for Environmental and Economic Sustainability).

One objective of Section E.4, **Building Durability, Adaptability and Disassembly**, is to conserve resources and extend the life of a building and its components by minimizing material replacement. The requirements include specifying durable and low-maintenance materials within its service environment, and designing for adaptability and easy disassembly. Architectural drawings and details, as well as mock-ups and testing, are required to address rain penetration control.

The Green Globes system outlines a method to select materials, based on embodied energy, through life cycle assessment, and makes references to durability, low-maintenance, and adaptability requirements. The system also references best practices for design of building envelope assemblies, detailing, and commissioning (e.g., mock-up, field review and testing). However, it does not establish the design service life of the building, assemblies and components to assist with appropriate material selection.

Built Green™

The Built Green™ program was released in 2003/2004 and is currently offered in Alberta and BC. The program was based on the Built Green™ Colorado program, but adopted National Research Canada's (NRCan) *EnerGuide* for new houses rating for the energy component, mandatory air tightness testing and NRCan's R2000 builder training program.

The Built Green™ program has three levels of achievement, Bronze, Silver and Gold. Points are awarded based on the minimum *EnerGuide* rating with additional points selected from each of the seven areas of the checklist to give a cumulative total. Each separate category has minimum point totals that must be selected.

The program encourages the use of "durable" materials that have a longer life cycle and require less maintenance, but does not discuss the principles behind durability, envelope design, performance, or service environment. The term durable is used as a material property, rather than a function within a given environment and a specific service life. For example, points are allotted for specific material use, such as brick and stucco or roofing materials with 25+ year warranties. There is no mention of best practice design, architectural details, mock-ups or testing, as outlined in this paper's proposed method of assessing durability.

LEED Canada NC version 1.0

Canadian Green Building Council's (CaGBC) LEED Canada is a rating system modeled after the USGBC LEED version 2.1 and LEED BC adaptation. There are 70 points in LEED Canada and four certification categories, Certified, Silver, Gold and Platinum. LEED Canada added one additional point to the USGBC LEED, to include the Materials and Resources credit 8.0 – Durable Building. There are no other references or aspects of durability found in the LEED Canada assessment tool. The following outlines the credit.

> The intent of **Materials and Resources credit 8.0 – Durable Building,** is to minimize materials use and waste over a building's life, resulting from premature failure of the building and its components. The credit uses the principles outlined in the CSA S478-95 (R2001) *Guideline on Durable Buildings* to meet the requirements of the credit. The users are required to use and submit (upon audit) the tables, as modeled within the guideline. The CSA guideline is a comprehensive document that is intended to assist designers and Owners in creating a durable building. It provides a methodology and framework in which to make decisions on durability. Sections include quality assurance, design service life, methods to predict service life (e.g., demonstrated effectiveness, modeling, and testing), design and construction considerations (e.g., LCC), and operating and maintenance

programs. The guideline also includes definitions, tables, sample projects, and appendix information.

LEED Canada has incorporated the CSA guideline as the method to assess durable buildings, but it has not integrated the credit through the assessment tool. The user is not required to select the durable building credit, nor use its guidelines for selecting other materials. For example, the selection of materials or assemblies as outlined in the Materials and Resources section (e.g., recycled materials, reused materials, regional materials, and rapidly renewable materials) does not require an assessment of their durability; rather their use is based on their history or geographic area. If LEED Canada incorporated the credit as a pre-requisite, as it has done with energy and water use, the intent of a durable building would be integrated into all other credits.

Considerable criticisms have been made with the format of the credit and the use of the CSA guideline to obtain the one credit in LEED Canada. To many professionals, unfamiliar with the guideline and envelope design principles, the credit requirements were seen as overwhelming. Many users searched unsuccessfully for a published document with prelisted material service lives to punch into the tables. Others avoided the credit, stating that it was too costly to achieve, and signing parties were too liable. This was not the intent of the Canadian Green Building Council and hopefully an addendum will address these concerns.

INTEGRATION AND SUMMARY

Green assessment tools have developed from an academic modeling purpose to a useful design and construction tool to measure sustainable building practices. Their future success will require the adaptation and modification to include the key waste stream areas of building construction as well as building operation. Although water and energy use have been addressed in the tools, the affects of building envelope failures and premature deterioration are just beginning to be recognized and implemented. However, the problem of assessing service lives and durability remains.

Two existing standards, the ISO 15686 and CSA S478-95, present methods to assess service life and building durability. The key focus of these standards is establishing service lives for the building as a whole, as well as each assembly component. Establishing service lives requires the general knowledge in building function and expected life, and specialized knowledge in building science and material properties. We have provided a proposed method to assess building durability throughout the design and construction period. However, the method or framework may not be suitable for all projects and hence should be used to develop a project specific durability plan for assessing and implementing the principles of durability.

Clearly the concept of durability has been considered in the earlier green assessment tools, such as GBTool and Green Globes. Although they typically relied on the design professionals to reference unspecified best practice guides, they did focus on the critical areas of detailing and commissioning. With some minor modifications, these tools could address all the major issues outlined in this paper's proposed assessment method. LEED Canada went in a different direction by using the CSA guideline and its sample documents. This tool could also be modified by changing the credit to a prerequisite, which would incorporate the principles of durability throughout the tool. Built Green has referenced the importance of building durability, but has not provided a method to assess service life or durability. This tool would require some significant changes to incorporate the principles of durability.

For assessment tools to be successful in achieving their purpose, the owners, designers and contractors must use them. Designing for durability requires a team to be focused on the concepts of durability from the outset of the project and to stay focused until completion, or even several years after that. The design team should periodically "check in" to make sure the project still reflects the original goals. Design teams will need to act in an integrated fashion, drawing upon the collective team experience, as well as that of manufacturers and material representatives, building scientists, and trade associations.

If the goal is to move towards a more sustainable built environment, assessment tools need to be used for all projects, regardless of their intent for certification through third parties. A clear and committed durability plan can help address at least one of the key waste streams in construction, that of resource use and depletion.

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