LEED benchmarking for lightweight structures

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INTRODUCTION

The built environment has a profound impact on our natural environment, economy, health, and productivity. Breakthroughs in building science, technology, and operations are now available to designers, builders, operators, and owners who want to build green and maximize both economic and environmental performance.

The LEED® green building certification program run by the U.S. Green Building Council (USGBC) is a leading program seeking to transform the built environment and provide a mechanism for the society in general and the construction industry in particular to respond to the important challenges of global climate change, dependence on non-renewable and ever more expensive sources of energy, constrained resources, and threats to human health.

This paper has an overview of the LEED program and uses it to benchmark the opportunities and challenges for lightweight structures. As part of this paper the sustainability of the main building materials used in lightweight structures are examined and compared.

LEED v3 GREEN BUILDING RATING SYSTEM

Following the formation of the U.S. Green Building Council (USGBC) in 1993, the organization's members quickly realized that the sustainable building industry needed a system to define and measure "green buildings." The first LEED Pilot Project Program was launched in 1998, and has had major revisions in 2000, 2005 and again in April this year.

LEED v3, launched on April 27, 2009 is an evolution from the previous version (v2.2) to take advantage of new technologies and advancements in building science while prioritizing energy efficiency and CO2 emissions reductions.

The LEED green building rating systems are voluntary, consensus-based, and market-driven. Based on existing and proven technology, they evaluate environmental performance from a whole building perspective over a building's life cycle, providing a definitive standard for what constitutes a green building in design, construction, and operation.

The LEED rating systems are designed for rating new and existing commercial, institutional, and residential buildings. They are based on accepted energy and environmental principles and strike a balance between known, established practices and emerging concepts. It promotes a whole-building approach to sustainability by recognizing performance in five key areas of human and environmental health:

- sustainable site development,
- water savings,
- energy efficiency,
- materials selection,
- indoor environmental quality.

To do this each rating system is organized into 5 environmental categories: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, and Indoor Environmental Quality. An additional category, Innovation in Design, addresses sustainable building expertise as well as design measures not covered under the 5 environmental categories. Regional bonus points are another feature of LEED and acknowledge the importance of local conditions in determining best environmental design and construction practices.

<u>The LEED Credits</u>
In LEED v3, the allocation of points between credits is based on the potential environmental impacts and human benefits of each credit with respect to a set of impact categories. The impacts are defined as the environmental or human effect of the design, construction, operation, and maintenance of the building, such as greenhouse gas emissions, fossil fuel use, toxins and carcinogens, air and water pollutants, indoor environmental conditions.

Credits that most directly address the most important impacts are given the greatest weight. The resulting changes increase the relative emphasis on the reduction of energy consumption and greenhouse gas emissions associated with building systems, transportation, the embodied energy of water, the embodied energy of materials, and where applicable, solid waste.

To provide incentive to address geographically specific environmental issues, USGBC regional councils and chapters have identified 6 credits per rating system that are of particular importance to specific areas.

Exemplary performance strategies result in performance that greatly exceeds the performance level or expands the scope required by an existing LEED v3 credit. To earn exemplary performance credits, teams must meet the performance level defined by the next step in the threshold progression.

<u>Certification Levels</u>
LEED v3 for New Construction and Major Renovations certifications are awarded according to the following scale:

Certified	40–49 points
Silver	50–59 points
Gold	60–79 points
Platinum	80 points and above

<u>Minimum Program Requirements</u>
The LEED v3 Minimum Program Requirements (MPRs) define the minimum characteristics that a project must possess in order to be eligible for certification under LEED v3. These requirements define the categories of buildings that the LEED rating systems were designed to evaluate, and taken together serve three goals: to give clear guidance to customers, to protect the integrity of the LEED program, and to reduce challenges that occur during the LEED certification process. The minimum requirements are:

1. Must comply with environmental laws.
2. Must be a building.
3. Must use a reasonable site boundary.
4. Must comply with minimum FTE & floor area requirements.
5. Must comply with minimum occupancy rates.
6. Registration and certification activity must comply with reasonable timetables and rating system sunset dates.
7. Must allow USGBC access to whole-building energy and water usage data
8. Must comply with a minimum building area to site area ratio

MATERIALS

The environmental impact of materials is a critical factor for the design, construction and operation of high-performance "green" buildings. A range of tools are available to assist with assessment of each material, ranging from the simple to complex. A brief summary is presented here of the characteristics of the main building materials used in lightweight structures, their positive and negative impacts and how their use can be improved.

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Concrete

Concrete is not typically associated with lightweight structures, but it will usually found at the very least in the foundations, and often can be part of the base frame from which the lightweight structure springs. Concrete's dominate role in the construction industry also warrants its inclusion in any discussion on the environmental aspects of the built environment.

Concrete is the second most widely used substance on earth after water, with in the order of 2.3 billion tonnes being produced annually. To produce one tonne of cement between 0.8 to one tonne of CO2 gases is produced. This is due to high temperatures required for production of cement and the fact that CO2 is a by-product of the calcination process. The result is that cement production accounts for 5% of the human-generated CO2 production worldwide.

Positive impacts:

- The majority of raw materials used are abundant and locally available.
- Concrete can incorporate high percentages of waste products from other industries both as cementitious material and as aggregate.
- Virtually no concrete waste goes to landfill. Crushed concrete can be used as aggregate or base material and the reinforcement is separated and recycled.
- Wood and steel forms are recycled when they become worn or obsolete. Virtually all reinforcing steel is made from recycled steel. Many cement plants burn waste-derived fuels such as spent solvents, used oils, and tires.

Negative impacts:

- Cast in place concrete elements are generally not reusable on other projects.
- Increased mass compared to other structural systems results in larger foundations.
- Transport of large volume, heavy mass material incurs additional environmental burdens
- Relatively high ecopoints score reflects high impacts under full life-cycle assessment
- Admixtures and form releasing agents can contain high toxicity or VOC's.
- Environmental and social impact of quarrying for concrete aggregates (water, noise, traffic, land).

Enhancements to sustainability objectives:

- Concrete is highly durable (when properly designed and cast) and requires little maintenance.
- Concrete can have a high quality surface finish, reducing the materials used in the building.
- Concrete has high thermal mass, which can be exploited to reduce heating and cooling demands in buildings.

Scope for Improvement:

- Minimize mass with ribbed slabs, use of voids, post-tensioning, etc.
- Design concrete structures that can be salvaged.
- Re-use foundations
- Replace cement with other products, including by-products.
- Use non-toxic form release agents.

Steel

World steel production in 2008 was 1330 million tonnes per year, and according to the International Energy Agency (IEA), the iron and steel industry accounts for approximately 4-5% of total world CO2 emissions. On average, 1.7 tonnes of carbon dioxide are emitted for every tonne of steel produced.

Positive impacts:

- Steel is salvageable and can be easily recycled. It can be used and reused without loss of properties.
- Given the standardised nature of steel sections, they offer an excellent opportunity to design for deconstruction.

- Taking advantage of steel's engineering properties facilitates long spans, giving floor spaces that are adaptable to different uses over time.
- Steel structures tend to be lighter and therefore require smaller foundations.
- Even the relatively thin concrete slabs on metal decking generally provide sufficient thermal mass for a day long high temperature event.

Negative impacts:
- Making steel is a very energy intensive process
- Recycling steel by melting scrap is a more energy efficient process (10-20% of the energy associated with making virgin steel), but current scrap recovery is only sufficient to make up about 40% of the world's demand for steel.

Scope for Improvement:
- Encourage reuse of steel first, before relying upon recycling.
- Technology transfer between manufacturers.
- Long-term substantial improvements will only come from new breakthrough technologies in steelmaking.

<u>Glass</u>
Positive impacts:
- Combinations of glass and light framing can produce a structure with reasonable embodied energy.
- 100% fully recyclable

Negative impacts:
- 1 tonne of glass produces between 500 and 900 kg of CO_2
- Low insulation for single layer ordinary glass.

Scope for improvement:
- Increase levels of recycling, dealing with issues of coatings.
- Increasing levels of reuse in existing form and alternative uses.

<u>Woven Fabrics</u>
Positive impacts:
- Given light weight of material, the embodied energy for the roof system is low.
- Demountable, allowing temporary use and relocation.

Negative impacts:
- Life span for PVC/Polyester fabrics is less main building components.

Scope for improvement:
- Increase durability of the fabric, to increase its design life.
- Increase degree of recycling of the fabric
- Fabric reuse and reutilisation for different applications
- Substitution of ecologically and economically relevant raw materials.

<u>ETFE Foil</u>
Positive impacts:
- Similar embodied energy as glass, but weight per square metre substantially less, with result that the embodied energy is 1% of that of similar glazed structures.
- Can be fully recycled and re-extruded into new panels.

Negative impacts:
- Requires energy, albeit small, to run the inflation pump system.
- Rain noise, noise break-in.

LIGHTWEIGHT STRUCTURES – LEED OPPORTUNITIES

Lightweight structures can assist garner LEED credits directly in the categories of shading and daylighting, and can contribute to optimizing energy performance of the buildings.

<u>Shading</u>
To reduce heat islands to minimize impacts on microclimates and human and wildlife habitats, LEED requires a strategy for 50% of the site hardscape (including roads, sidewalks, courtyards and parking lots). An alternative is to provide shade from architectural devices or structures that have a solar reflectance index (SRI) of at least 29.

LEED Credit: SS Credit 7.1: Heat Island Effect—Nonroof

Note: The solar reflectance index (SRI) is a measure of the constructed surface's ability to reflect solar heat, as shown by a small temperature rise. It is defined so that a standard black surface (reflectance 0.05, emittance 0.90) is 0 and a standard white surface (reflectance 0.80, emittance 0.90) is 100. To calculate the SRI for a given material, obtain the reflectance value and emittance value for the material. SRI is calculated according to ASTM E 1980.

<u>Daylighting</u>
Daylighting, or more generally lighting, is one of the fundamental components of the built environment. In addition to revealing and structuring volumes, producing visual effects and providing character to a space, it must adequately respond to our needs for visual comfort, a connection to the outside world and a healthy environment. Lighting must also be carefully planned to be ecologically viable.

In terms of a building's environmental impact, the potential for saving energy using daylight is undisputable. For the US, buildings represent 40% of total energy use and about a third of that energy is generally dedicated to lighting.

In addition, careful management of daylight can help to increase solar gains in winter and decrease them in summer, allowing significant reductions in cost and energy use for warming and cooling. On the other hand, numerous scientific studies have demonstrated that human productivity and well-being might be positively affected by the availability of daylight (if properly controlled) and access to a view.

Translucent fabric membrane roofs can capitalize on the sun's benefits by allowing daylight to pass through to the interior of a structure. This natural and diffused sun lighting effect evenly illuminates interior spaces without creating a harsh glare. Tensile architecture offers clients the opportunity to create enclosed spaces that are functional and welcoming while being cost-effective.

LEED Credit: IE Q Credit 8.1: Daylight and Views—Daylight

<u>Optimizing Energy Performance</u>
One of the key aims of LEED is to reduce environmental and economic impacts associated with excessive energy use. There are up to 19 points available by achieving increasing levels of energy performance beyond the prerequisite standard. Achieving substantial enhanced energy performance will require the input of the whole of the design team.

Lightweight canopies and roofs can provide a high level of solar shading, have the opportunity to provide semi-conditioned spaces and can reduce solar heat gain within a structure. These can help to contribute to a project gaining an additional credit(s) for energy performance.

LEED Credit: EA Credit 1: Optimize Energy Performance

LIGHTWEIGHT STRUCTURES – OTHER SUSTAINABILITY CHALLENGES

LEED has been a great design and market transformation tool. However, it is lacking some significant ways in which the structure can contribute to true sustainable design – esp. embodied energy and life cycle considerations. Lightweight structures have opportunities and challenges to how it can contribute to the wider scope of true sustainable design.

Reduced Material Usage
Tensile architecture is an efficient form of architectural design and construction, fulfilling all functional requirements while using the least amount of materials possible. By using advanced design techniques, structures requiring far less structural materials are achievable, helping to produce cost-efficient and elegant structures with minimized environmental impact. Reduced materials consumption lowers the overall embodied energy of the building, which has a direct impact on the building's carbon footprint.

Increasing Design Life
Improving design life of the product, by new base materials and or protective coating systems, will reduce the demand for new materials.

Increase the Recycling of Materials
Most of the main materials used in lightweight structures are able to be recycled, as discussed in the material section earlier. The complexity arises from having to deal with the coatings and combination of materials within a product. The challenge is to incorporate the ability for recycling of the product at the end of its useful life into the design and manufacturing process of the product.

Increasing the Insulation Levels
A significant issue for PVC/polyester and PTFE/glass fabrics are their low mass and therefore low insulation levels. To expand the use of lightweight roof systems in non-temperate climates, the challenge of improving the insulating performance of the roofs will be a key item to solve.

A comparison of typical insulation levels are:

Material	**U-Value** (W/m2K)
Glass – single clear	5.4
Glass – double glazing	2.6
Glass – double glazing, with low-E glass	1.8
PVC/Polyester – single layer	4.5
PTFE/Glass – single layer	4.5
Twin layers with 200mm (8") air gap	2.6
Tensotherm (50mm thick)	0.5

Birdair Inc has recently developed an insulated fabric membrane (Tensotherm™ product which has PTFE/glass fabric combined with Nanogel® insulation). Their first project using this project was completed earlier this year, and with a 50mm thick overall thickness they achieved insulation values 9 times that of a single layer of fabric, whilst still maintaining a light transmission of 3.5%.

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CONCLUSION

The built environment has a profound impact on our natural environment, economy, health, and productivity. LEED® is a system for measuring the degree to which a building tackles these impacts, and provides a mechanism for the society in general and the construction industry in particular to respond to the important challenges of global climate change, dependence on non-renewable sources of energy, constrained resources, and threats to human health.

However it is but a system and can sometimes end up being worked as such, rather than following the true course to meet the actual objectives that lie behind the system. We want to avoid green washing, and to provide a meaningful contribution to address the challenges of climate change, energy availability and constrained resources. I believe it is an imperative course of action which will become more compelling as each year passes.

Lightweight structures, whilst not at the forefront of the issues facing the building industry, have opportunities to contribute to improving the environmental performance of the built environment. By their very nature, lightweight structures minimise material use. There is a need to look beyond this, to how to make each structure more durable, and how to assist with lowering the overall energy use of the building and improve the ambience of the internal environment.

To quote from USGBC “The work of innovative building professionals is a fundamental driving force in the green building moment. Such leadership is a critical component to achieving USGBC’s mission of a sustainable built environment for all within a generation.”

We can be part of the solution if we want to. It’s up to us to decide.

References:

1. USGBC - LEED 2009 for New Construction and Major Renovations, December 2008