SUSTAINABLE ASPECTS OF SEGMENTAL CONCRETE PAVEMENT

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SUMMARY

Rapidly rising energy and material costs have accelerated energy and natural resource conservation in civil engineering design and construction. The evolution of sustainable development provides a response to energy conservation while contributing to an environment that enhances human well being. Sustainable development can be broadly defined as that which meets the needs of the present without compromising the ability of future generations to meet their needs.

The North American design community has begun to embrace sustainable design through the adoption of Leadership in Energy and Environmental Design or LEED®. Developed by the U.S. Green Building Council (USGBC) in 1998, LEED® is a voluntary system of evaluating building and site designs through a rating system that encourages technologies that reduce energy and conserve non-renewable resources. The Canadian Green Building Council (CaGBC) was formed in 2003 and provides similar guidelines tailored to Canadian climates.

This paper will discuss the role of segmental concrete paving systems for new construction and major renovations as it applies to the two rating systems with that recognize sustainable design through a credit system. These are the CaGBC rating system (LEED®-NC 1.0) and the USGBC rating system (LEED®-NC 2.2). Segmental concrete pavements can contribute to S*ustainable Site* (SS) credits under stormwater management by incorporating permeable interlocking concrete pavement systems (PICP's) that reduce the rate and quantity of surface runoff and pollutants such as total suspended solids (TSS) and total phosphorous (TP). Under sustainable site credits, credits earned from segmental concrete pavements that reduce the heat island effect in roof and non-roof applications. Such products can also qualify for Material *and Resources* (MR) credits by providing solutions to construction waste management, resource reuse, recycled content, regional manufacture and extraction, and exclusive to Canada, a durability credit. Finally, segmental pavements can also achieve credits under *Innovation and Design Process* (ID).

1. INTRODUCTION

Rapidly rising energy and material costs have accelerated energy and natural resource conservation

in civil engineering design and construction. The evolution of sustainable development provides a response to energy conservation issues while contributing to an environment that enhances human well being. The most recognized definition of sustainability was established at the 1987 UN World Commission on Environment and Development, where it was defined as "that which meets the needs of the present without compromising the ability of future generations to meet their needs."

Segmental concrete paving systems have long been considered a sustainable form of paving. There is a rich history behind segmental concrete pavement, much of it developed by Dutch and Germans since the 1950's, and much of the construction technology can find its roots in the Romans roads of antiquity. The Romans built an 80,500 km intra-state network of roads with segmental pavement and some of these 2,000 year-old pavement sections are still with us today. Indeed, it is said that our own recent developments of paving systems seem to parallel Roman developments (Knapton, 1996). Many of the concepts developed then are used in interlocking concrete pavements today.

2. THE LEED® PROCESS

The North American design community has begun to embrace sustainable design through the adoption of LEED® (Leadership in Energy and Environmental Design), developed by the US Green Building Council (USGBC) in 1998. LEED® is a voluntary system of design for buildings and sites that provides a rating system which encourages the use of technologies that reduce energy and conserve non-renewable resources. The Canadian Green Building Council (CaGBC) was formed in 2003. USGBC released their latest version, LEED®-NC 2.2 for New Construction and Major Renovations in 2006. LEED® Canada version 1.0 is an adaptation of the USGBC LEED® green building rating system, tailored to Canadian climates, construction practices and regulations. The next Canadian version is expected in 2007. The CaGBC defines green building design as that which strives to balance environmental responsibility, resource efficiency, occupant comfort and well-being, community development and the economics of building construction and operation (CaGBC, 2004).

3. LEED® CREDITS

LEED® establishes a consensus-based means for measuring building and site performance and promotes designs that integrate energy and resource conservation. One of the primary objectives of LEED® is to help facility owners reduce maintenance and life-cycle costs. For new commercial construction (or LEED® – NC), the U.S. and Canadian Green Building Councils grant certification based on the same number of points (credits) earned from each rating system. The minimum number of earned points is 26 for a project to be certified as sustainable. Higher ratings are also possible; *Silver* for a project that earns 33 to 38 points, *Gold* for 39 to 51 points and *Platinum* for 52 or more points.

Points are earned by fulfilling the requirements and prerequisites as specified in each credit. Prerequisites and credits are organized in five principal LEED® categories; Sustainable Sites (SS), Water Efficiency (WE), Energy and Atmosphere (EA), Material and Resources (MR), Indoor Environmental Quality (IQ). An additional category, Innovation and Design Process (ID) recognizes expertise in green design and construction and measures not covered under the five aforementioned categories. Segmental concrete paving systems can be shown to contribute to 14 points under the SS, MR, and ID credits.

3.1. Sustainable Site (SS) Credits

The intent of the SS performance credits are to encourage site selection, planning, landscaping and design strategies that use land more effectively and minimize construction and operational impacts. There are 14 points available in the SS category through eight credits. Segmental concrete pavements can contribute to four points in two of these credits by fulfilling the requirements and prerequisites under Stormwater Management and Heat Island Effect.

3.1.1. Stormwater Management (SS Credit 6)

The stormwater management credits are concerned with the rate, quantity and quality of stormwater runoff. The rate and quantity of stormwater runoff is dependent on the amount of pervious and impervious surfaces on a building site. While pre-developed sites may allow infiltration of the majority of precipitation, the amount of post-development runoff can be significantly increased in urban areas. This results in adverse environmental impacts such as flooding, habitat loss, erosion, stream bed alteration and channel widening (US EPA, 1997). In addition, these stormwater runoffs contain sediment and pollutants that have a negative impact on water quality and water supplies. Permeable interlocking concrete pavements (PICP's) mitigate these impacts and can achieve the credits (See Figure 1). A typical design consists of solid concrete pavers with openings at their edges or placed with larger joints. The openings are filled with small sized, open-graded crushed stone and built on an open-graded aggregate base and subbase. The ICPI publication, *Permeable Interlocking Concrete Pavements* (ICPI, 2006) offers design, specification, construction and maintenance guidance for these pavements. A summary of the design procedure is found in the paper entitled "Permeable Interlocking concrete Pavements – Selection, Design, Construction and Maintenance" (Burak, 2003)

3.1.1.1. Stormwater Management: Rate and Quantity (SS Credit 6.1)

USGBC and CaGBC LEED® credit SS6.1 both give one credit for sites with less than 50% net imperviousness where the designer has implemented a stormwater management plan that prevents the post development 1.5 year (CaGBC) and one and two-year (USGBC), 24-hour peak discharge rate from exceeding the pre-development discharge rate from the same storms. For CaGBC audit purposes the designer must show, through pre-construction and post-construction site drawings, that there has been no increase in net imperviousness of the site. USGBC requires the designer to provide a LEED letter template, signed by the civil engineer or responsible party, confirming the above requirements.

For sites where the net imperviousness is greater than 50%, the designer must show that they have implemented a stormwater management plan that results in a 25% decrease in the rate and quantity of stormwater runoff. This is for a 1.5 year 24-hour design storm in Canada and a two-year 24-hour design storm in the United States. For CaGBC audit purposes the designer must provide a copy of the storm water management plan. USGBC requires the designer to provide a LEED letter template, signed by the civil engineer or responsible party, confirming the above requirements.



Figure 1. This permeable pavement has been in service at the Toronto Harbourfront Fire Station since 1998.

PICP's can be used to meet the prerequisites for both of the conditions described above. The long-term conservative pavement surface infiltration rate is approximately 200 mm/hour (Ferguson, 2005). The ICPI manual (2006) conservatively uses 75 mm/hour as the lifetime surface infiltration rate. For the purposes of calculating site perviousness, PICP's are given a runoff coefficient (C value) of 0.25 to 0.4 depending on the soil conditions. Low C values should be used in high – infiltration sandy soils and higher values for lower-infiltration silt and clay soils (ICPI 2005). These runoff coefficients are similar to grass turf areas recommended by CaGBC (CaGBC, 2004).

3.1.1.2. Stormwater Management: Treatment (SS Credit 6.2)
Roof, sidewalks, driveways, and streets contribute additional runoff and pollutants as well as denying infiltration of stormwater. CaGBC LEED® credit SS6.2 gives one credit to sites where the stormwater treatment systems are designed to remove 80% of the average annual post-development total suspended solids (TSS) and 40% of the average annual post-development total phosphorus (TP) based on the average annual loadings from all storms less than or equal to the 2-year, 24-hour storm. The designer is required to implement Best Management Practices (BMP's) outlined by the United States Environmental Protection Agency (USEPA, 1993).

USGBC requires the designer to implement a stormwater management plan that reduces impermeable cover, promotes infiltration and captures and treats stormwater runoff from 90% of the average annual rainfall using acceptable best management practices. In addition, the BMP's must be capable of removing 80% of the average annual post development total suspended solids based on existing monitoring reports. PICP's are shown to meet both of the objectives through base designs with high storage capacities.
Since PICP reduces runoff through infiltration, it has the ability to reduce TSS and TP. Studies have demonstrated 80% reduction of TSS (James, 1997) and (Rushton, 2001). Studies that demonstrate at least 40% TP reduction include (James, 1997), (Rushton, 2001) and (Bean, 2005). These studies compared reductions in pollutants from PICP to that from impervious pavements. Like the USGRC requirements, CaGBC states that treatment of first flush is critical to successful treatment strategies, and that if a project can demonstrate that 100% of the first 25 mm of rainfall is fully infiltrated on site

and/or collected in rainfall cisterns, the intent of this credit would also be achieved. 25 mm of rainfall will include 90% of all storms.

3.1.2. Heat Island Effect (SS Credit 7)

The heat island credits are concerned with reducing heat islands (the thermal difference between developed and undeveloped areas) in order to minimize the impact on microclimate and human and wildlife habitat. Heat island effects can artificially raise the temperatures of urban areas by more than 5.5 degrees Celsius when compared to undeveloped suburban areas. There are two credits, non-roof and roof. Segmental concrete paving can meet many of the submittal requirements.

3.1.2.1. Heat Island Effect: Non-roof (SS Credit 7.1)

For the non-roof credit CaGBC requires the designer to provide tree shade within five years and/or use light coloured, high albedo materials with a reflectance of 0.3 and/or open grid pavements for at least 30% of the sites non-roof impervious surfaces, including parking lots, walkways and plazas. Alternatively, a designer can choose to place a minimum of 50% of parking spaces underground or covered by structured parking. A final alternative is to use an open-grid pavement system (less than 50% impervious) for a minimum of 50% of the parking lot area. One credit is awarded for compliance to this requirement.

USGBC requires the designer to provide any combination of the following strategies over 50% of the site hardscape (including roads, sidewalks, courtyards and parking lots); shade within 5 years of occupancy, paving materials with a solar reflectance index (SRI) of at least 29, and an open grid pavement system. Alternatively the designer can place at least 50% of the parking spaces under cover with the roof of the parking lot having a minimum SRI of 29.

SRI is a measure of the constructed surfaces ability to reflect solar heat. 0 on the scale represents standard black and 100 represents standard white. SRI is calculated according to ASTM E 1980 (2001) and requires both the reflectance value and the emittance value for the material. Reflectance is measured according to ASTM E 903 (1996) and emittance is measured according to ASTM E 408 (2002). Many segmental concrete products meet the minimum SRI requirement of 29 by use of special cements, coloured pigments, or special aggregates.

Standard grey cement concrete has a reflectance of 0.35 to 0.40 when new and 0.20 to 0.30 when weathered. Concrete products can be manufactured with a combination of light coloured cements and light coloured aggregates to meet the minimum reflectance requirements of this credit. White cement concrete products can far exceed the reflectance values with an albedo of 0.7 to 0.8 when new and 0.4 to 0.6 when weathered.

Concrete grid pavements with grass (See Figure 2) have also been shown to contribute some microclimate cooling benefits. Compared to asphalt, grassed grid pavements, through evapo-transpiration, will reduce surface air temperatures by 1 to 2 degrees Celsius (Smith, 1981). Open grid pavements meet the requirement of having less than 50% impervious paving surface.



Figure 2: Concrete grid pavement with grass can be used to achieve the LEED® credit SS 7.1 Heat Island: Non Roof.

3.1.2.2. Heat Island Effect: Roof (SS Credit 7.2)
For the heat island effect roof credit CaGBC requires the designer to use ENERGY STAR® compliant (highly reflective) roof materials, or a high thermal emissivity (at least 0.9) roofing material, or to install a "green" vegetated roof for at least 50% of the roof area. ENERGY STAR® is a U.S. government rating system to assess the ability of roof material to reflect solar radiation, which reduces air conditioning loads. Concrete pavers and paving slabs can be tested to determine their solar reflectance or albedo and sourced to meet these requirements. More often, designers will integrate a strategy of incorporating combined reflective/low emittance roofing products with a vegetated green roof. The aforementioned concrete grid pavements with grass infill can be incorporated as part of the "green" vegetated roof. One point is awarded for compliance to this requirement.

USGBC requires roofing materials with SRI values greater than or equal to 78 for low sloped roofs and greater than or equal to 29 for high sloped roofs, for a minimum of 75% of the roof area. Another alternative is to install a combination of vegetated roof with high albedo materials such that the following formula is satisfied:

(1) (Area of SRI roof/0.75) + (Area of vegetated roof/0.5) ≥ Total Roof Area

3.2. Materials and Resources (MR) Credits
The intent of the material and resource category to encourage design strategies that reduce and reuse material resources and reduce construction waste and to encourage the selection of environmentally preferable building materials. There are 15 points available for the Material and Resources Category through 8 credits. Segmental concrete pavements can contribute to nine points in five of these credits by satisfying the partial requirements and prerequisites under Construction Waste Management, Resource Reuse, Recycled Content, Regional Materials, and in Canada, Durable Building.

3.2.1. Construction Waste Management (MR 2.1 and 2.2)
High tipping (disposal) fees at landfills and threat of soil and groundwater pollution have forced the recycling of construction and demolition waste. For the CaGBC and USGBC credit, the construction waste management credits award one point under MR 2.1 for a waste management plan that quantifies non-hazardous material diversion of at least 50% through recycling and/or salvaging of construction, demolition, and land clearing waste. An additional one point is awarded under MR 2.2 if the project exhibits material diversion of at least 75%.

Segmental concrete products can contribute to these credits in several ways. Used concrete pavers or slabs can be removed from a site, reprocessed at a recycler through crushing, and reused on a new site for pavement base material. If the project involves renovating an existing site, concrete pavers from the site can be re-used or directed to other appropriate sites. The contribution of the pavers or slabs can be quantified by weight and added to the other materials on the site that also qualify.

3.2.2. Resource Reuse (MR 3.1 and 3.2)
The intent of the material and resource credits is to encourage the reuse of materials and products in order to reduce the demand for virgin materials and to reduce waste. For both the CaGBC and the USGBC credit, one point is awarded under MR 3.1 if the total amount of salvaged, refurbished or reused materials, products or furnishings accounts for at least 5% of the total building material costs. An additional 1 point credit is awarded under MR 3.2 if the project exhibits resource reuse of at least 10% of the total building material costs.

A material salvaged during a building renovation an be applied to this credit only if it can no longer serve its original function and has been reprocessed and installed for a different use. An example would be crushing salvaged concrete pavers or slabs for reuse as pavement base material.

On a project where an existing building is being demolished or deconstructed, the material salvaged and installed on the new site can be used to comply with this credit. In this case, if pavers were salvaged, the market value of new pavers would be used to calculate the salvage rate by dividing the salvaged material market value by the total project material costs.

3.2.3. Recycled Content (MR 4.1 and 4.2)
The intent of the recycled content credits is to increase the demand for building products that incorporate recycled content materials, therefore reducing impacts resulting from extraction and processing of new virgin materials and by-passing energy and green house gas-intensive industrial and manufacturing processes. For CaGBC, the recycled content credit awards 1 point under MR 4.1 if the total recycled content (post consumer + ½ post-industrial) is at least 7.5% and awards an additional point under MR 4.2 if the recycled content is at least 15% (both based on cost of the total value of building materials). For USGBC the recycled contents are 10% and 20% respectively.

Segmental concrete products can be made with recycled materials and contribute to this credit. A portion of the cement can be replaced with supplementary cementing materials (SCM's) such as flyash, silica fume, and ground granulated blast furnace slag. These materials are used to calculate the post-industrial recycled content. The percentage in Portland cement reduction is calculated by comparing the cement content of a base mix with that of a mix with SCM's. This is then multiplied by a factor of two to account for the environmental merits of reducing Portland cement (which reduces the amount of greenhouse gases emitted by cement production). The dollar value is calculated and the

result is added to post-consumer and other post-industrial contributions from other materials used on the project. A percentage of the total material costs can then be determined.

3.2.3. Regional Materials (MR 5.1 and 5.2)
The intent of the regional material credits is to increase the demand for building materials and products extracted and manufactured within the region, thereby supporting the indigenous resource use and reducing the environmental impacts resulting from long distance transportation. Under these requirements, one point is awarded under MR 5.1 for CaGBC for a minimum of 10% of building materials or products used and at least 80% of the mass is extracted, processed and manufactured within 800 km of the project site. For USGBC the requirement is the same except that it can be calculated on whatever the material percentage extracted/harvested/recovered and manufactured locally, calculated on a weight basis. For CaGBC, if shipping is by rail or water, the allowable distance is increased to 2400 km and a combination of the two transportation methods can also be used. Under MR 5.2, for both CaGBC and USGBC the same criteria exist, except that 20% must be extracted and manufactured regionally to qualify for an additional credit. For segmental concrete paving products these criteria can be verified by the manufacturer and their material sources.

3.2.4. Durable Materials (MR 8)
A unique addition to LEED® Canada fills credit MR 8 – Durable Building. The this credit intends to minimize materials use and construction waste over a building's life resulting from premature failure of the building and its constituent components and assemblies. The designer is required to develop a building durability plan in accordance with the principles outlined in CSA S478-95 (R2001) – Guideline on Durability in Buildings.

This guideline also encourages the use of readily replaced construction components and assemblies and strategies that allow for ease of access for repairs. Designing for deconstruction and adaptability is recognized as extending the life of building components and buildings as a whole. The modular nature of all segmental concrete paving products enables easy access to underground utility repairs and reinstatement of the same paving units with no waste or damage to the surface (ICPI, 2005).

3.3. Innovation and Design Process Credit (ID)
The Innovation and Design Process Credit category enables designers to incorporate innovative improvements in building materials and design into the LEED® rating system. In addition to innovative design, credits may also be awarded if a project achieves exceptional performance under an existing LEED® credit for that project. Examples may include using water infiltrated through a PICP pavement and exfiltrating it to a system for landscape irrigation or for grey water use in a building. Generally, ID credits are awarded for existing credits if the requirements are doubled. Another innovative use for segmental concrete paving products might be to use their re-instatement characteristics as part of the lifetime maintenance plan. In this scenario, all outside utilities can be designed to be accessible below segmental concrete pavements such that at any time access can be made to the utility and the same material reinstated after repairs.

4. CONCLUSIONS

The USGBC website is www.usgbc.org and the CaGBC website is www.cagbc.ca. The LEED® rating system recognizes leading-edge buildings that incorporate design, construction and operational practices that combine healthy, high-quality and high-performance advantages with reduced environmental impacts. Segmental concrete products have been shown to contribute to this mandate in

the categories of sustainable sites, water efficiency, materials and resources, durability and innovation and design process. Segmental concrete paving products have been recognized as contributing to a sustainable environment reduce environmental impacts. One means to judge environmental impacts is life-cycle assessment. The British Green Guide to Specification (BREAM 2002) offers impacts ratings of various pavement materials based on climate change, fossil fuel depletion, human toxicity to air and water, waste disposal, water extraction, acid deposition, ecotoxicity, eutrophication, summer smog, minerals extraction, replacement intervals, recycled content, recyclability, energy savings and initial cost. Using this rating system, segmental concrete pavements yield the least impacts to the environment and humans.

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