USING CONCRETE TO CONSTRUCT GREEN BUILDINGS

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Abstract
The LEED™ Green Building Rating System™ is a point-based system for certifying the level of a building's sustainability. Appropriate use of concrete can help a building earn up to 19 points out of the 26 required for certification. Using concrete can help in brownfield redevelopment, reduce urban heat islands, reduce water runoff, help meet minimum energy requirements, optimize energy performance, and increase the life of a building. The constituents of concrete can be recycled materials, and concrete can be recycled. Concrete and its constituents are usually available locally. These attributes of concrete can help lessen the impact a building has on the natural environment.

Introduction

The Leadership in Energy and Environmental Design (LEED) Green Building Rating System is a voluntary, consensus-based national standard for developing high-performance, sustainable buildings. LEED is both a *standard* for certification and a *design guide* for sustainable construction and operation. LEED is administered by the U.S. Green Building Council (USGBC). This paper discusses LEED 2.1, which applies to commercial, institutional, and high-rise residential new construction and major renovation.

Essentially, *LEED* is a point-based system that *provides a framework for assessing building performance and meeting sustainability goals.* Points are awarded when a specific intent is met, and a building is LEED certified if it obtains at least 26 points. The points are grouped into five categories: (i) sustainable sites, (ii) water efficiency, (iii) energy and atmosphere, (iv) materials and resources, and (v) indoor environmental quality. Besides the 26 points required for certification, the more points earned, the "greener" the building. Silver, gold, and platinum ratings are awarded for at least 33, 39, and 52 points, respectively.

Appropriate use of concrete can help a building earn up to 19 points out of the 26 required for LEED certification. Using concrete can help in brownfield redevelopment, reduce urban heat islands, reduce water runoff, help meet minimum energy requirements, optimize energy performance, and increase the life of a building. The constituents of concrete can be recycled materials, and concrete itself can also be recycled. Concrete and its constituents are usually available locally. These attributes of concrete, recognized in the LEED rating system, can help lessen a building's impact on the natural environment.

Sustainability is often defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Although most of us are concerned with the present and future health of the natural environment, too few of us are willing to pay more for a building or product that minimizes environmental burdens. LEED, however, balances sustainable design with cost-effectiveness.

A sustainable design can result in reduced project costs and a building that is energy and resource efficient. Energy and water efficient buildings have lower operating costs than conventional buildings: in the range of \$6 to \$16 versus \$19 per m^2 (\$0.60 to \$1.50 versus \$1.80 per ft^2). Lower energy costs translate into smaller capacity-requirements for mechanical heating and cooling equipment and lower first costs for such equipment. Effective use of daylighting and passive solar techniques can further reduce heating and cooling costs. Reusing materials, such as demolished concrete for base or fill material, can reduce hauling and landfill costs. If sustainability is an objective at the outset of the design process, the cost of a sustainable building is competitive (USGBC, 2002a).

Buildings with daylighting and good indoor air quality—both common features of sustainable buildings—have increased labor productivity, worker retention, and days worked. These benefits contribute directly to a company's profits because salaries—which are about ten times higher than rent, utilities, and maintenance combined—are the largest expense for most companies occupying office space. In schools with daylighting and good indoor air quality, students have higher test scores and lower absenteeism.

Many U.S. government agencies require that buildings meet LEED requirements, although they do not necessarily require LEED certification. Some examples include the General Services Administration, which owns or leases over 8300 buildings, and the U.S. Army, which has adopted LEED into its Sustainable Project Rating Tool (SPiRiT). In addition, many municipalities and local government agencies are considering requiring LEED certification for public buildings or tax credits.

Concrete and the LEED Point System

The most current version of LEED is 2.1. The LEED points are grouped into credits that are further grouped into the five categories mentioned earlier. Most credits are worth 1 point, but some—the ones with a higher potential to reduce environmental burdens—are worth more. For all credits, specific auditing or record keeping requirements must be met. A free copy of LEED version 2.1 can be download from the website www.USGBC.org.

Cement is a fine powder that, when mixed with water, sand, and crushed stone or gravel, makes concrete. Cement and concrete have the potential to earn points under the following LEED categories:

Sustainable Sites

Brownfield Redevelopment. Cement can be used to solidify and stabilize contaminated soils and reduce leaching concentrations to below regulatory levels. Documentation is required indicating the site was contaminated and the remediation performed. This credit is worth 1 point.

Stormwater Management: Rate and Quantity. On building sites where the existing imperviousness is greater then 50%, pervious concrete pavements can be used to help reduce the rate and quantity of storm water runoff. The technical requirement for this credit requires reducing the rate and quantity of stormwater runoff by 25%. Pervious concrete contains coarse aggregate (crushed stone or gravel), little or no fine aggregate (sand), and insufficient cement paste to fill the voids between the coarse aggregate. It results in concrete with a high volume of voids (20% to 35%) and a high permeability that allows water to flow through easily. Similar results can be achieved by using concrete pavers that have large voids where vegetation can grow. This credit is worth 1 point.

Heat Island Effect: Non-Roof. One way to attain this credit is to "use light-colored/high-albedo materials (reflectance of at least 0.3) for 30% of the site's non-roof impervious surfaces." This requirement can be met by using portland cement concrete rather than asphalt concrete for 30% of all sidewalks, parking lots, drives and other non-roof impervious surfaces. The city of Chicago is applying for LEED certification using this credit for a public library with concrete sidewalks as shown in Figure 1. This credit is worth 1 point.

Figure 1. The City of Chicago is applying for LEED certification for this public library with concrete sidewalks.

Albedo, which in this context is synonymous with solar reflectance, is the ratio of the amount of solar radiation reflected from a material to the amount that shines on the material. Solar radiation includes the ultraviolet as well as the visible spectrum. Generally, light-colored surfaces have a high albedo, but this is not always the case. Surfaces with lower albedos absorb more solar radiation. The absorbed radiation is converted into heat and the surface gets hotter. Pavements with higher albedos absorb less energy and are thus cooler. Where paved surfaces are required, using materials with higher albedos will reduce the heat island effect—consequently saving energy by reducing the demand for air conditioning—and improve air quality.

Portland cement concrete typically has an albedo of approximately 0.35 although values can vary. Measured values are reported in the range of 0.4 to 0.5. For “white” portland cement, values are reported in the range of 0.7 to 0.8 (Levinston, et al., 2001). New asphalt concrete generally has a reflectance of approximately 0.05 and asphalt concrete five or more years old has a reflectance of approximately 0.10 to 0.15.

Energy and Atmosphere

Minimum Energy Performance. All buildings must “meet building energy efficiency and performance as required by the ANSI/ASHRAE/ IESNA Standard 90.1-1999 (ASHRAE, 1999) or the local energy code, whichever is the more stringent.” The ASHRAE standard is usually more stringent and applies for most states. The requirements of the ASHRAE standard are cost-effective and not particularly restrictive for concrete. It is generally economical to insulate to meet or exceed the requirements of the code. This item is a prerequisite for LEED certification and is not worth any LEED points.

Determining compliance for the envelope components is relatively straightforward using the tables in Appendix B of the ASHRAE standard. Minimum requirements are provided for mass and non-mass components such as walls and floors. Building components constructed of concrete generally are considered “mass.” This means the components have enough heat-storage capacity to moderate daily temperature swings. Buildings with high thermal mass, such as buildings built of insulated concrete forms (ICF), concrete, or concrete masonry units, moderate indoor temperature extremes and reduce peak heating and cooling loads. In many climates, they have overall lower energy consumption than non-massive buildings with walls of similar thermal resistance (Gajda, 2001), and heating, ventilating, and air-conditioning can be met with a smaller-capacity equipment system.

Optimize Energy Performance. This credit is worth 1 to 10 points. The points are awarded if energy cost savings can be shown when compared to a base-line building that meets the requirements of ASHRAE 90.1-1999. The method of determining energy cost savings must meet the requirements of Section 11 of the ASHRAE standard. Section 11 requires modeling a building to determine energy savings as required using a computer-based program, such as DOE 2.(Eley Associates, 1999). When concrete is considered, it is important to use a program such as DOE 2 that calculates yearly energy consumption on an hourly basis. Such programs are needed to capture the beneficial thermal mass effects of concrete. Many analyses that are done gratuitously by HVAC manufacturers do not have this capability.

Insulated concrete wall systems, used in conjunction with other energy saving measures, will most likely be eligible for points. The number of points awarded will depend on the building, climate, fuel costs, and minimum requirements of ASHRAE 90.1-1999. From 1 to 10 points are awarded for energy cost savings of 15 to 60% for new buildings and 5 to 50% for existing buildings.

Materials and Resources

Building Reuse. The purpose of this credit is to encourage reusing the building structure and shell. The building shell includes the exterior skin and framing but excludes window assemblies, interior walls, floor coverings, and ceiling systems. This credit should be obtainable when renovating buildings with a concrete skin because the concrete components of a building generally have a long life. This credit is worth 1 point if 75% of the existing building structure and shell is left in place and 2 points if 100% is left in place.

Construction Waste Management. This credit is earned for diverting construction, demolition, and land clearing waste from landfills. It is awarded based on diverting at least 50% (by weight) of the previously listed materials for a given project. Because concrete is a heavy construction material and is frequently recycled into aggregate for road bases or construction fill (ACPA, 1993 and ACI, 2001), this credit should be obtainable when concrete buildings are demolished.

This credit is worth 1 point if 50% of the construction, demolition, and land-clearing waste is recycled or salvaged and 2 points for 75%. For concrete, either the credit for building reuse or the credit for construction waste management can be applied for, but not both, because the concrete structure is either reused or recycled into another use.

Recycled Content. The requirements of this credit state: “use materials with recycled content such that post-consumer recycled content constitutes at least 5% of the total value of the materials in the project OR combined post-consumer and one-half of the post-industrial recycled content constitutes at least 10%.” The building material percentages are determined on a cost basis. The sample calculations in the LEED Reference Guide (USGBC, 2002b) show how to calculate recycled content. Supplementary cementitious materials, such as fly ash, silica fume, and slag cement (PCA, 2002) used as a partial replacement for portland cement are considered post-industrial. Furthermore, using recycled aggregates instead of extracted aggregates would qualify as post-consumer. Because concrete is an assembly, its recycled content should be calculated as a percentage of recycled material on a mass basis. Although most reinforcing bar is manufactured from recycled steel, and would probably qualify, it would not be considered as part of concrete. This credit is worth 1 point for the quantities quoted above and 2 points for an additional 5% post-consumer recycled content OR an additional 10% combined post-consumer and post-industrial recycled content.

Regional Materials. The requirements of this credit state: “use a minimum of 20% of building materials and products that are manufactured regionally within a radius of 500 miles (800 km).” Concrete will usually qualify since ready-mix plants are generally within 50 miles (80 km) of most job sites. Furthermore, precast concrete would also qualify because precast plants are located near urban areas.

The percentage of materials is calculated on a cost basis. This credit is worth 1 point. One additional point is earned if 50% of the regionally manufactured materials are extracted, harvested, or recovered within 500 miles (800 km). Ready-mix and precast plants generally use aggregates that are extracted within 50 miles (80 km) of the plant and most building projects will be within 50 miles (80 km) of a ready-mix plant.

Cement and supplementary cementitious materials used for buildings are also generally extracted and manufactured within 500 miles (800 km) of a job site. Reinforcing steel is also usually manufactured within 500 miles (800 km) of a job site, and is usually made from recycled materials from the same region.

Others Points

Concrete can also be used to get points indirectly. The Pennsylvania Department of Environmental Protection building in Harrisburg, Pennsylvania is LEED Bronze certified and features a concrete floor with low-VOC sealant. This allowed the building to obtain the Low Emitting Materials credit under Indoor Environmental Quality.

In addition to the points discussed above, four points are available under Innovation Credits. These points can be applied for if an innovative green design strategy is used that does not fit into the point structure of the five LEED categories or if it goes significantly beyond a credit requirement. For example, the USGBC has issued a credit interpretation that allows for an innovation credit if 40% of the cement in concrete is replaced with fly ash. However, using fly ash in this range is not common, so addition precautions should be considered (see Marceau, et al., 2002 for an explanation of these precautions).

Other Sustainability Characteristics of Concrete

Concrete has other sustainability characteristics that are not recognized by LEED. Some of these include:

Concrete as exterior walls and roofs is a strong, durable material resistant to building and forest fires, hurricanes, and wind. “Safe rooms” constructed of masonry within residences and other buildings offer additional protection. Exterior walls of concrete offer more security to building and home owners and require less maintenance than conventional siding materials.

Concrete is not damaged by moisture, and generally can “breathe” and dry if not prohibited by other adjacent materials.

Concrete walls reduce sound transmission and provide quieter residences and offices. Sound barriers on highways are often constructed of concrete and masonry to reduce traffic noise adjacent to residential areas.

The materials used to manufacture cement (mostly clay and limestone) and concrete (generally cement, crushed rock, gravel, and sand) are abundant in most countries and are not scarce resources.

Table 1: Summary of Possible Points to Increase LEED Ratings of Buildings

Category	Number of points		
	Total possible	Using concrete	
		Number	% of total
Sustainable sites	14	3	14
Water efficiency	5	0	0
Energy and atmosphere	17	10	59
Materials and resources	13	6	46
Indoor environmental quality	15	0	0
Innovation credits	4	0*	0
LEED-accredited professional	1	0	0
Total	**69**	**19**	**26**

*More are possible: see text.

Summary
In the LEED system, as many as 19 points can be earned through the appropriate use of concrete on a green building project. The points are summarized in Table 1. The points awarded can help a building become LEED certified or help a building obtain a higher level of certification. A sustainable design can take advantage of the benefits of concrete to lessen a building's impact on the natural environment.

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