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Clean, Green and Sustainable Building Elements: Masonry and Brick

Muge Mukaddes Darwish, Mary Frances Agnello
Texas Tech University, Lubbock, Texas, USA
mukaddes.darwish@ttu.edu, maryfrances.agnello@ttu.edu

Abstract
Masonry and brick have a long history of successful use because of their design flexibility, durability, low maintenance, as well as variety of colors, shapes, textures, and sizes. Moreover, an unsurpassed life cycle, exceptional energy efficiency, natural ingredients, minimal waste, and countless recycling options are just a few of the properties that make masonry and brick superb green sustainable materials for sustainable building design. This discussion will focus on the natural fit between sustainable design and masonry.

The U.S. Green Building Council defines sustainable design: as the practices of design and construction that significantly reduce or eliminate the negative impact of buildings on the environment and occupants in six broad categories: sustainable site planning, safeguard water and water efficiency, energy efficiency and renewable energy, conservation of materials and resources, indoor environmental quality, and innovation and design process. In addition to describing masonry and brick as a clean, green, and sustainable building material, the research here highlights the Leadership in Energy and Environmental Design (LEED) Green Building Rating System and the role of masonry in LEED construction.

Keywords
Sustainability, Construction, Masonry, Brick, LEED

1. Introduction

Sustainability is a global trend that has captured worldwide attention. In the U.S.A there is an increasing demand, in both public and private sectors, to understand sustainable design and construction practices. This demand is driven by realization of sustainable practices, that not only help the environment, but that can also improve economic profitability and improve relationships among many stakeholder groups whose missions have great impact on the environment.

Sustainable design considers a building's environmental implications holistically, from the planning process to the building's deconstruction at the end of its useful life (Montoya, 2008). Sustainability is defined as "*meeting the needs of the present without compromising the ability of future generations to meet their own needs*" (ASTM E 2114-06a). Sustainable buildings are designed in a way that use available resources efficiently and responsibly, balancing environmental, societal and economic impacts to meet the design intents of today while considering future effects. Sustainably designed buildings are energy-efficient, water-efficient and resource-efficient. They address the well-being of the occupants by considering thermal comfort, acoustics, indoor air quality and visual comfort in the design. They also consider the impact of a building's construction, operation, and maintenance on the environment, as well as the environmental impact of the building's constituent materials. A sustainably designed building considers all of these aspects throughout the entire life cycle of the building, including its operation and maintenance on the environment (BIA technical Notes, 2008).

The terms *sustainable building*, *green or high performance building design and construction* are often used interchangeably. Regarding the whole life cycle of building, the concern is environmental awareness; such consideration addresses the ecological, social, and economic ramifications of a building in a community from the planning process to the deconstruction of its useful life and further recyclability of the materials that were used to construct it. Kibert (2008) defines *green building* referring to the quality and characteristics of the actual structure created using the principles and methodologies of sustainable construction. Whether the references are to sustainable building, green design or construction or to green building, the terms all denote the same concept that a construction decision about made today should not negatively impact future generations to come.

1.1 USGBC (United State Green Building Council)

The **U.S. Green Building Council** is a 501(c)(3) non-profit community of leaders working to make green buildings available to everyone within a generation. It was formed in 1993 and took four years to develop LEED building rating system.

So what is LEED? And the LEED rating system?

The Leadership in Energy and Environmental Design (LEED) Green building system encourages and accelerates global adoption of sustainable green building and development practices through the creation and implementation of universally understood and accepted tools and performance criteria. The organization has been defined as a third-party certification program and the nationally accepted benchmark for the design, construction and operation of high performance green buildings (USGBC, web site retrieved 1/11/2009). LEED is a national voluntary program that gives building owners and operators the tools they need to have an immediate and measurable impact on their buildings' performances.

1.2 Green Building Assessment

In 1998, the USGBC established the "Green Building Rating System", a common standard for the measurement of what constitutes a high performance green building. LEED 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 and indoor environmental quality. Buildings are LEED-certified if they achieve these ends (USGBC, web site retrieved 1/11/2009).

1.3 LEED Certification Process

Buildings are certified by LEED if they achieve a minimum of 26 points out of a possible 69 points in the rating system. LEED certification of a building can be achieved at different levels based on a set of required "prerequisites" and a variety of "credits" in the six major categories. These categories are:

1. Sustainable sites (SS) 14 points,
2. Water efficiency (WE) 5 points,
3. Energy and atmosphere (EA) 17 points
4. Materials and resources (MR) 13 points
5. indoor environmental quality (IQ) 15 points
6. Innovation and design process (ID) 4 points+1point for having LEED-AP on the design team

In LEED V2.2, new construction and major renovations for commercial buildings can qualify for four levels of certification:

1. LEED Certified- 26-32 points
2. LEED Silver Certification- 33-38 points
3. LEED Gold Certification- 39-51 points
4. LEED Platinum Certification- 52 -69 points

2. LEED and Masonry

More often than not, in construction, the tendency is to consider only one aspect of building design, rather than given energy use or the environmental impacts of it. Sustainable design should consider all the six aspects of the categories listed by the USGBC-LEED in order that a balance of environmental, societal, and economic goals can be achieved. A high performance green building design should include safety, accessibly, durability, aesthetics, health and productivity of occupants, operation/maintenance, security and energy efficiency and ecological and environmental performance. The whole design and built process must not consider only one element but should use a holistic approach drawing from the knowledge of pool of all the stakeholders across the life cycle of the project, from defining the need of the building, through planning, design, construction, building occupancy, and operations (NIBS, web site revised 1/10/2009).

Although each building has some unique requirements based on the users' needs, some other components must be considered for the high performance sustainable buildings and buildings. These components, according to Roadman and Lenssen (1995) are environmentally responsive site planning, energy – efficient building shell, thermal comfort, energy analysis, renewable energy, safety and security, day lighting, high-performance lighting, commissioning, environmentally preferable materials, high-performance HVAC, high-performance electric lighting, life cycle cost analysis, acoustic comfort, superior indoor air quality, and visual comfort.

No products alone can satisfy all of these requirements and components; therefore careful planning and choice of materials is necessary in the design and construction of a high performance green building. Masonry and brick have been used successfully for sustainable construction because of its design flexibility, durability, low maintenance, environmental friendliness (not needing volatile paints), and its variety of color and shapes. Application of new technology in the use of sustainable energy for manufacturing points to masonry and brick as natural choices for sustainable building materials.

3. Masonry Contributions to LEED Credits Adopted from Christine A. Subasic (P.E., Leed Ap)

Sustainable sites (SS): By using permeable concrete or brick masonry pavements or open cell concrete masonry pavers, masonry can contribute up to three points in this category.

Credit 6.1: Stormwater Management — Rate and Quantity
The intent of this credit is to limit disruption and pollution of natural water flows by managing or eliminating stormwater runoff by increasing on-site infiltration and eliminating contaminants. One point is awarded if, for a site with an existing imperiousness less than or equal to 50%, the post-development 1.5 year, 24-hour peak discharge rate does not exceed the pre-development rate; or if, for a site with an existing imperviousness greater than 50%, the rate and quantity of stormwater runoff is decreased by 25%.

Credit 6.2: Stormwater Management — Treatment
The intent of this credit awarded in this category is the same as for Credit 6.1. One point is awarded for stormwater treatment systems designed to remove 80% of the average annual post-development total suspended solids (TSS) and 40% of the average annual post-development total phosphorous (TP). Recommended best management practices for achieving this credit include the use of porous pavements.

Credit 7.1: Heat Island Effect — Non-Roof
The intent of this credit is to reduce heat islands to minimize impact on microclimate and human and wildlife habitat. One point is awarded if shade and/or light-colored/high-albedo materials and/or open-grid pavement are provided for at least 30% of the site's non-roof impervious surfaces. Or one point can

be awarded for the use of an open-grid pavement system (less than 50% impervious) for a minimum of 50% of the parking lot area.

3.1 Energy and Atmosphere (EA)

Masonry can contribute to achieving points in this category by harvesting site energy (using passive solar designs) and decreasing the size of the building HVAC system. The thermal mass inherent in masonry reduces temperature swings, stores heat/cooling for release at later times, and reduces peak energy loads. Strategies like these reduce the size of the HVAC system required, thus saving energy and cost during the life of the building.

Credit 1 — Optimize Energy Performance

This is intended to achieve increasing levels of energy performance above the prerequisite standard. One to 10 points can be awarded for improvements of 15 to 60% above the standard for new buildings or 5 to 50% improvement for existing buildings. The baseline standard used is *ASHRAE /IESNA 90.1-1999.* Improvements in performance are measured using the Energy Cost Budget Method found in Section 11 of the ASHRAE standard.

3.2 Materials and Resources (MR)

Masonry can contribute up to 11 points (out of 13) toward LEED certification in this category. Credits are given for building materials harvested and manufactured locally, for materials with recycled content, and for reuse of building materials — all being areas to which masonry can contribute.

Credit 1 — Building Reuse

The intent of this credit is to extend the life cycle of existing building stock, conserve resources, retain cultural resources, reduce waste and reduce environmental impacts of new buildings. Credit 1.1 awards one point for 75% reuse of existing walls, floors and roof. Credit 1.2 gives one additional point for maintaining 100% of the existing walls, floors and roof. Changes proposed for LEED version 2.2 lower these thresholds to 40% and 80% respectively, making it easier to qualify. Credit 1.3 awards one additional point for reuse of 50% of interior non-structural elements. Non-structural masonry walls and floors can contribute to this point.

Credit 2 — Construction Waste Management

The intent of this credit is to divert construction, demolition and land clearing debris from landfill disposal. Scraps and broken pieces of concrete masonry can be crushed and used for aggregate or fill. Clay brick scraps can be crushed and used for landscaping as brick chips. Intact, unused masonry units can be saved to use on another project, or donated to Habitat for Humanity or other charitable organizations. One point is awarded for diversion of 50% of the construction, demolition and land clearing waste (Credit 2.1). One additional point is awarded for diverting 75% (Credit 2.2). Calculations can be done on a weight or volume basis.

Credit 3 — Resource Reuse

This credit is intended for reuse of salvaged materials and products to reduce the demand for virgin products. Materials salvaged on site do not apply to this credit, but do count toward Credit 1 — Building Reuse. Masonry materials such as brick can be salvaged, but the Brick Industry Association warns against their use. Used brick may not meet the requirements of present-day specifications and may not bond properly. Paver bricks that are salvaged and used for interior applications on a new building meet the

intent of this credit. Up to two points can be earned for use of salvaged building materials for 5% and 10% of building materials (Credits 3.1 and 3.2).

Credit 4 — Recycled Content

This credit is intended to increase demand for building products that incorporate recycled content materials, therefore reducing impacts resulting from extraction and processing of new virgin materials. This credit awards up to two points for using building products that incorporate recycled content materials. Because of the inert nature of masonry products, they are ideal candidates for incorporating recycled materials. The requirement for one point is that materials with the sum of post-consumer recycled content plus 1/2 the post-industrial content constitute at least 5% of the total value of materials in the project (Credit 4.1). If the sum of post-consumer recycled content plus 1/2 the post-industrial content equals 10% or more, one additional point is awarded (Credit 4.2).

Concrete masonry units often incorporate recycled materials. According to the (National Concrete Masonry Association (NCMA), supplementary cementitious materials such as fly ash, silica fume and slag cement are considered post-industrial materials. Concrete masonry that incorporates recycled concrete masonry, glass, slag or other recycled materials as aggregate qualify as post-consumer (TEK 6-9A).

Clay brick often incorporate recycled brick ground and used as grog. If reclaimed from a job site, this material can qualify as post-consumer recycled content. Some manufacturers use bottom ash, a post-industrial waste, for 10 to 12% (by weight) of the clay body. Other post-industrial materials used include fly ash and even sludge. Because of the inert properties of brick, even contaminated soil and sawdust are used. One company uses waste from a nearby ceramic whiteware manufacturer as grog.

Mortar may contain recycled materials such as fly ash. Steel reinforcing bars used in reinforced masonry may contain post-consumer or post-industrial materials.

Credit 5 — Regional Materials

This credit encourages the use of building materials that are extracted and manufactured within the region, thereby supporting the regional economy and reducing the environmental impacts resulting from transportation. Masonry products can contribute to one point when 20% of the building materials and products are manufactured within a 500-mile radius of the project site (Credit 5.1). One additional point is earned if the regionally manufactured materials use a minimum of 50% of building materials that are extracted, harvested or recovered within 500 miles of the project site (Credit 5.2). Changes to the specifics of this credit are proposed for LEED 2.2

3.3 Innovation in Design (ID)

The intent of this category is to recognize exceptional performance beyond the requirements in LEED or reward innovations in categories not specifically addressed by LEED. Credit 1 awards one point for each innovation up to a total of four points. Possible areas where masonry can contribute include: acoustic performance, life-cycle cost and durability, efficient use of materials with prestressed or reinforced masonry and improved air quality by reducing the need for paint or interior coatings (thereby reducing volatile organic compounds, or VOCs) and by reducing the possibility of mold growth. Such credits require the applicant to write the intent and requirements of the credit. These credits are typically awarded for having a building-wide approach that addresses a sustainable feature such as those listed above. For example, a credit could be written for improved air quality beyond that required in LEED EQ (Indoor Environmental Quality) Credit 4 — Low Emitting Materials by choosing materials throughout the building that do not require paint or coatings such as glazed masonry in toilet and janitorial rooms, brick

pavers for flooring, architectural concrete masonry for walls, etc. All materials used in the building would be considered, and masonry could be a large contributor to achieving the intent. Credit 2 gives one point for having a LEED-accredited professional on the design team.

With the use of "Greenest Brick" developed and patented by Freight Pipeline Company (FPC) in the U.S.A. which is made entirely of fly ash, it is expected to gain more points for masonry from the LEED Grading system.

In Table 1, possible contributions that brick and masonry can make to sustainable design are delineated.

Table 1: Potential Sustainable Design Contributions from Brickwork

(Adopted from BIA Technical Notes)

	LEED-NC[1]	Green Globes[2]	LEED for Homes[3]	NAHB National Green Building Standard[4]
Environmentally Responsive Sites				
Reuse Existing Buildings. Brick masonry buildings can be renovated and reused.	Materials & Resources (MR) Credit 1 –3 points	Resources, Building Materials and Solid Waste (Resources) E.3 – up to 10 points		Site Design and Development (SD) 403.9 – 6 points, and Resource Efficiency (RE) – up to 12 points
Urban Development. Brick masonry is suitable and highly adaptable to urban infill projects.	Sustainable Sites (SS) Credit 2 – 1 point	Site B.1.1 – up to 20 points	Location & Linkage (LL) – 3.1 – 1 point or LL 3.2 –1 point	SD 401.1 – 4 points; and Lot Design, Preparation and Development (LD) 501.1 – 4 points
Location on Site. Site building to optimize solar radiation (passive solar heating and cooling pos-sible).Maintain open space (brick construction requires minimal disruption of site).	SS Credit 5.2 – 1 point		Innovation & Design (ID) 1.5 – 1 point	SD 403.2 – 6 points
Storm Water Design. Reduce quantity and improve quality of runoff with permeable brick pavements.	SS Credit 6 – 2 points	SiteB3.1 –up to 10 points	SS Credit 4.1 –4 points	SD 403.5 – up to 5 points and LD 503.4 – up to 5 points
Heat Island Effect. Light-colored pavers can help reduce heat build-up.	SS Credit 7 –2 points	Site B.2.5 – up to 10 points	SS 3 –1 point	LD 505.2 –4 points
Energy Efficiency, Thermal Comfort and Energy Analysis				
Improved Energy Performance. Thermal mass of brick helps reduce heat transfer; pressure-equalized brick rain screen walls.	Energy & Atmosphere (EA) Credit 1 – up to 10 points	EnergyC.1.1 –up to 100 points	Energy & Atmosphere (EA) 1 – up to 34 points	Energy Efficiency (EE) 703.1.3 – up to 6 points and EE 704.3.1 – up to 7 points
Thermal Comfort. Thermal mass of brick helps reduce indoor temperature swings.	EA Credit 1 – up to 10 points	Energy C.1.1 – up to 100 points	Energy & Atmosphere (EA) 1 – up to 34 points	Energy Efficiency (EE) 703.1.3 – up to 6 points and EE 704.3.1 – up to 7 points
Energy Analysis. Energy modeling reflects benefits of thermal mass of brick.	EA Credit 1 – up to 10 points	Energy C.1.1 – up to 100 points	Energy & Atmosphere (EA) 1 – up to 34 points	Energy Efficiency (EE) 703.1.3 – up to 6 points and EE 704.3.1 – up to 7 points
Environmentally Preferable Materials				

1. LEED-NC version 2.2 – Total possible points = 69
2. Green Globes Design v.1 – Post Construction Assessment – Total possible points = 1000
3. LEED for Homes (January 2008) – Total possible points = 136
4. NAHB National Green Building Standard, Draft 2 (2008) – Total possible points = approximately 2000

Table 1: Potential Sustainable Design Contributions from Brickwork (Continued)

	LEED-NC1	Green Globes2	LEED for Homes3	NAHB National Green Building Standard4
Life Cycle Assessment.	Innovation & Design (ID) Credit 1 – 1 point	Resources E.1 – up to 40 points	Materials & Resources (MR) Credit 2.2 – up to 8 points	RE 609.1 – 3 points per product
Avoidance of Construction Waste. Use modular designs to avoid waste.				RE 601.3 – 3 points
Recycling of Construction Waste. Brick and packaging are 100% recyclable.	Materials & Resources (MR) Credit 2 – 2 points	Resources E.5.1 – 6 points	MR Credit 3.2 – 3 points	RE605.1 –6 points
Salvaged Materials. Salvaged brick and pavers can be reused.	MR Credit 3 – 2 points	Resources E.2.1 – 10 points	MR 2.2 – ½ point per product	RE 603.2 – 3 points
Recycled Content. Brick may contain recycled sawdust, sludge, metallic oxides. Mortar/grout may use fly ash.	MR Credit 4 – 2 points	Resources E.2.2 – 10 points	MR 2.2 – ½ point per product	RE 604.1 – up to 6 points
Regional Materials. Brick manufacturing plants are located near raw materials and available throughout the United States.	MR Credit 5 –2 points		MR 2.2 – ½ point per product	RE 608.1 – 2 points per material
Materials That Do Not Require On-site Finishes. No finishes are required of brickwork, can be used inside as well.				RE 601.7 – 2 or 5 points for each material
Materials Made with Renewable Energy. Several brick manufacturers use landfill gas or sawdust to fire their brick.				RE 606.3 – 2 for each material
Durability and Design for Service Life				
Durability. Brick has a useful life of more than 100 years.				
Termite Resistant Materials in Areas of Termite Infestation. Insects do not eat brick.		Emissions and Other Impacts F.5 – 1 point	SS 5 – up to 1 point	RE 602.8 – up to 6 points
Weather-resistant Barrier or Drainage Plane Inside Siding or Veneer. Brick veneer introduced the drainage wall.		ResourcesE.4.1 – 2 points		RE 2.2.9 – 8 points
Flashing. Flashing is always present in well-detailed brick buildings.		Resources E.4.1 – 2 points		RE 602.12 – 6 points
Renewable Energy				
Renewable Energy. Thermal mass of brick walls and floors can be used in passive solar designs.	EA Credit 1 – up to 10 points	Energy C.1.1 – up to 100 points		Energy Efficiency (EE) 3.3.5.1 B. – 10 points
Safety and Security				
Fire-resistant Construction. Brick will not burn or emit toxic fumes.				
Impact-resistant Construction. Brick masonry resists damage from wind-borne debris and other impacts.				
Efficient Use of Materials				

1. LEED-NC version 2.2 – Total possible points = 69
2. Green Globes Design v.1 – Post Construction Assessment – Total possible points = 1000
3. LEED for Homes (January 2008) – Total possible points = 136
4. NAHB National Green Building Standard, Draft 2 (2008) – Total possible points = approximately 2000

Table 1: Potential Sustainable Design Contributions from Brickwork (Continued)

	LEED-NC[1]	Green Globes[2]	LEED for Homes[3]	NAHB National Green Building Standard[4]
Materials with Multiple Functions. Brick walls can serve as structure and finish, provide acoustic separation, and provide thermal mass.				RE 601.9 – 4 points
Use Products that Contain Fewer Resources than Traditional Products. Thinner brick units use less material and weigh less; hollow brick units use less material and can be reinforced.				RE607.1 – 3 for each material
Foundations that Require Less Material. Pier and panel foundations of brick meet this practice.				RE 601.8 – 3 points
Structural Systems That Optimize Material Use. Engineering design, rather than empirical design, of brick walls provides better utilization of materials.				RE 601.2 – 3 points
Acoustic Comfort				
Acoustic Comfort. Brick walls provide an STC of 45 or higher		Indoor Environment (IE) G.5 – 10 points		
Superior Indoor Air Quality				
Avoid VOCs. Interior brick walls avoid paints. Interior brick floors avoid carpets and adhesives.	Indoor Environmental Quality (EQ) Credit 4.2 – 1 point EQ Credit 4.3 –1 point	IEG.2.9 – 4 points	MR 2.2 – ½ point per product MR 2.2 – ½ point per product	IE 901.8 – number of points depends on application IE 901.8 – number of points depends on application
Mold. With moisture-tolerant materials and finishes, brick is not a food source for mold and can be easily cleaned.		IE G.2.1 – 1 point		
Miscellaneous				
Product manufacturer is ISO14001 certified.				RE 610.1 – 1 point per percent

1. LEED-NC version 2.2 – Total possible points = 69
2. Green Globes Design v.1 – Post Construction Assessment – Total possible points = 1000
3. LEED for Homes (January 2008) – Total possible points = 136
4. NAHB National Green Building Standard, Draft 2 (2008) – Total possible points = approximately 2000

4. Conclusion

Sustainability is a global trend that has captured worldwide attention. In the U.S.A., there is an increasing demand, in both public and private sectors, to understand sustainable design and construction practices. This demand is driven by many stakeholder groups that realize the value of sustainable practices, that not only help the environment, but that can also improve economic profitability and improve relationships within.

As the population of the world increases, there is now a larger demand for resources and energy than in the past few decades, which in turn creates a rise in pollution. Buildings which use about 48 % of all energy consumed in the United States are the biggest contributors to pollution. As environmental awareness becomes popularized in the mainstream, the populous looks towards greener and more

sustainable construction, such as those proposed in the green building system. The savings offered by energy efficient buildings will pay for their extra cost in only a few years because the cost of energy is rising. Cognizant builders understand that a green building offers pure savings in the future, rather than costing more, as is the case with traditional unsustainable construction.

Masonry, as a long-lasting and durable material, is a logical green building material. Mason contractors who educate themselves about how to do green construction will be in demand when green construction contractors are looking for masons with experience.

Sustainable construction is more than a certificate from a rating system; it also balances design with environmental, economic, and societal goals. Because brick can be made in abundance from recycled materials, brick manufacturers can address sustainability by locating plants near mines, by incorporating waste products into the bricks. Thoughtful planning can reduce energy and fuel costs. Utilizing landfill gas and other wastes for fuel is also possible in the manufacturing of brick.

Some other assets of brick and masonry make it a natural durable material for sustainable and versatile usage in structure, finish, acoustic and thermal comfort, indoor air quality, fire and impact resistance. At a time when many of our buildings are sick and are contributing to illness in their inhabitants, brickwork is a boon for eliminating the need for paints and volatile organic compounds (VOCs), while at the same time eliminating a food source for mold. Because brickwork has a life expectancy of hundreds of years, buildings constructed with them can be used and re-used, thereby distributing their impact on the environment over many years. As sustainable/green designed builders address the entire life cycle of the building, including operation, maintenance and reconstructing, they will find brick and masonry to respond.

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