Chapter 13

Sustainability

How Structural Lightweight Aggregate Contributes to a Long-Term Holistic Approach to Sustainability for the Concrete Community

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CHAPTER 13

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13.1 How a 2000 Year Old Industry Found Itself on the Leading Edge of Sustainable Construction

The sustainability movement is gaining momentum and has come to the forefront of the construction industry. This shift in attitudes and lifestyle awareness has caused the industry as well as traditional building product manufacturers to evaluate themselves from a green perspective. When the rotary kiln produced structural lightweight aggregate industry took a look into the uses and manufacturing of their products they were pleasantly surprised. Structural lightweight aggregate (SLA) has been successfully used for well over two millennia with widespread use for the past eighty years. It has been used in a multitude of applications that supported sustainable design long before the current green movement came to the forefront. This Chapter will highlight some of these areas and show the diversity of a common product that is used frequently in established construction practices.

Structural lightweight aggregate has a track record of proven performance and years of successful construction use. It has contributed to sustainable development by conserving energy, lowering shipping requirements, maximizing structural efficiency and increasing concrete service life of structures. The use of lightweight aggregate in site development has assisted designers in addressing the important issue of storm water management with on site treatment. Additionally, SLA helps to reduce heat island effects by amending soils to improve landscaping and through its use in both intensive and extensive roof top gardens. SLA's unique features allow it to be used in a multitude of applications that contribute to the sustainability of the site and structure.

13.2 A Holistic Approach to Sustainability for the Concrete Community

The future viability of the concrete community will be determined by its response to the global issue of sustainability. New research and technology, and the rapid development of the green building movement clearly point out that change in current life styles are essential if we are to maintain and improve our way of life. In 2002 the U.S. Green Building Council accelerated the activity and interest in sustainable design and construction. Their already popular "LEED" (Leadership in Energy and Environmental Design) rating system was advanced and may soon provide the basis on which all designs are built. The monumental importance of energy efficient building designs was pointed out in the Metropolis October 2003 article "Turning Down the Global Thermostat". In this article Edward Mazria's (well known architect and author) startling conclusions are reported:

> “Architects – together with the building industry are responsible for just about half of America’s energy consumption and half its greenhouse gas emissions, which are produced by burning coal, gasoline and other fossil fuels”.

Attitudes of the concrete community as with all other groups need to be revised to meet the demands and challenges of green buildings and future generations. One of these changes includes the use of materials that will extend the service life of concrete and additionally make concrete a contributor to the more efficient use of energy and raw materials. This paper covers the use of structural lightweight aggregate in concrete and demonstrates how this addition can benefit the entire concrete community.

Lightweight aggregate has been successfully used for well over two millennia with widespread use in the past eighty years. It is this track record of proven performance that interests the design community, owners and researchers. This Chapter also shows how lightweight aggregate contributes to sustainable development by maximizing structural efficiency, conserving energy, lowering transportation requirements, and improving concrete durability.

We use the generally adopted definition of “sustainable development” presented by the 1987 UN World Commission on Environment and Development: “Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs”.

13.3 What is Rotary Kiln Produced Structural Lightweight Aggregate and How Does it Interface With Concrete

SLA is a ceramic material produced by expanding and vitrifying select shales, clays, and slates in a rotary kiln. The process produces a high quality ceramic aggregate that is structurally strong, durable, environmentally inert, light in weight, and highly insulative. It is a natural, non-toxic, absorptive aggregate that is dimensionally stable and will not degrade over time.

Product Evaluation – Structural Lightweight Aggregate

The first step toward designing sustainable structures is product evaluation. How is the product made? Is the product an efficient use of the raw materials? How will the product perform? What happens to the product when its useful life is over?

Structural lightweight aggregates are produced in manufacturing plants from raw materials, including suitable shales, clays, slates, fly ashes, or blast-furnace slags. Naturally occurring lightweight aggregates are mined from volcanic deposits that include pumice and scoria. Pyroprocessing methods include the rotary kiln process where raw material is fed into a long, slowly rotating, slightly inclined cylinder where it’s fired in excess of 1000°C. This manufacturing process is similar to portland cement. The manufacturing processes are producing a uniform, high quality ceramic product that is structurally strong, stable, durable and inert, yet also lightweight and insulative. No single description of raw material processing is all-inclusive, and the reader is urged to consult local lightweight aggregate manufacturers for physical and mechanical properties of lightweight aggregates and the concrete made with them.

The increase usage of processed lightweight aggregates is evidence of environmentally sound planning, as these products have lower transportation requirements and use raw materials that have limited structural applications in their natural state. This minimizes demands on finite resources of quality natural sands, stones and gravels.

Lightweight aggregates have a low-particle relative density because of the cellular pore system. The cellular structure within the particles is normally developed by heating certain raw materials to incipient fusion; at this temperature, gases are evolved within the pyroplastic mass, causing expansion, which is retained upon cooling. Strong, durable, lightweight aggregates contain a uniformly distributed system of pores that have a size range of approximately 5 to 300μm, developed in a continuous, relatively crack-free, high-strength vitreous phase. Pores close to the surface are readily permeable and fill with water within the first few hours of exposure to moisture. Interior pores, however, fill extremely slowly, with many months of submersion required to approach saturation. A small fraction of interior pores are essentially non-interconnected and remain unfilled after years of immersion (ACI 213R-03).

The ceramic nature of the aggregate insures the product is inert and highly resistant to degradation, thereby providing concrete with a key component that has stood the test of time. These same properties also render the product environmentally benign in that it can be reused as fill or base material. In many applications, the aggregate is blended into soils that benefit from the water absorbing characteristics of its pores nature which provide a nutritional and moisture buffer that modify climate and environmental changes.

Product Interface – Structural Lightweight Aggregate in Concrete

An essential step toward sustainability is evaluating how the product interfaces with adjacent products and what effect this has on the performance of the combined material, in this case structural lightweight concrete.

Concrete failing prematurely should not be tolerated. Whether by microcracks or macrocracks, a major source of failure is initiated at cracks. Therefore, mitigating cracking becomes an essential element in sustainability. Adding lightweight aggregate to concrete mitigates crack formation, as demonstrated in the following narrative.

Core samples taken from hulls of 80-year-old lightweight concrete ships as well as 40 to 50-year-old lightweight concrete bridges reveal that the concrete has a dense contact zone at the lightweight aggregate/cement matrix interface. This zone has very low levels of microcracking throughout the mortar matrix (Sturm et al. 1999). Explanation for this high resistance to weathering and corrosion involves several physical and chemical mechanisms including superior resistance to microcracking. This excellent performance is developed by the significantly higher aggregate/matrix adhesion and the reduction of internal stresses due to elastic matching of coarse aggregate and matrix phases (Holm, Bremner, and Newman 1984). High ultimate strain capacity is also provided by lightweight concrete as it has a high strength/modulus ratio. The strain at which the disruptive dilation of concrete starts is higher for lightweight concrete than for equal-strength normalweight concrete. A well-dispersed pore system provided by the surface of the lightweight fine aggregates may also assist the air-entrainment system and serve an absorption function by reducing concentration levels of deleterious materials in the matrix phase.

Permeability investigations conducted on lightweight and normalweight concrete exposed to the same testing criteria have been reported by numerous researchers Khokrin (1973), Nishi et al. (1980), Keeton (1970), Bamforth (1987), Bremner et al. (1992). It is of interest that, in every case, despite wide variations in concrete strengths, testing media (water, gas, and oil), and testing techniques (specimen size, media pressure, and equipment), lightweight concrete had equal or significantly lower permeability than its normalweight counterpart. Khokrin (1973) further reported that the lower permeability of lightweight concrete was attributed to the elastic compatibility of the constituents and the enhanced bond between the coarse lightweight aggregate and the matrix.

One principal difference between lightweight concrete and normalweight concrete is the development and positive influence of the contact zone. The contact zone in lightweight concrete is the interface between two porous media: the lightweight aggregate particle and the hydrating cementitious binder and has been demonstrated to be significantly superior to that of normalweight concrete. This improvement in the quality, integrity, and microstructure stems from a number of characteristics unique to lightweight concrete, including but not limited to the following:

- The alumina and silicate rich pozzolanic surface of the fired ceramic aggregate combines with the $Ca(OH_2)$ liberated by hydration of the portland cement;
- Reduced microcracking at the matrix lightweight aggregate interface because of the elastic similarity of the aggregate and the surrounding cementitious matrix

  The modulus of elasticity of concrete depends on the relative amounts of paste and aggregate and the modulus of each constituent. Elastic incompatibility of the constituents of normalweight concrete result from the higher moduli of sand, stone, and gravel that are all significantly greater than the moduli of lightweight aggregate particles.

Essentially, a lower E_c value for lightweight concrete results in a reduced stiffness, as defined by the product of modulus of elasticity and moment of inertia, *EI*. Reduced stiffness can be beneficial at times in cases requiring improved flexural response, such as bridges, structures where differential settlement may occur.

- Hygrol equilibrium between the two porous phases: lightweight aggregate and a porous cementitious matrix is fundamentally different than the usual condition with dense aggregates, where bleed-water lenses form around the non-absorbent coarse natural aggregates that have a *w/cm* ratio significantly higher than the matrix. The accumulated water at the interface is subsequently lost during drying leaving voids and a weak low-quality aggregate/matrix interface (ACI 213R-03).

  When pozzolans are added, the high-quality microstructure of the contact zone of concrete containing lightweight aggregate is moderately enhanced. In contrast, when high-quality pozzolans are used in concretes containing normalweight aggregates, this zone of weakness is significantly improved.
- With lightweight concrete the cementitious hydration is enhanced due to the process of internal curing. Time-dependent improvement in the quality of concrete containing lightweight aggregate is greater than that with normalweight aggregate. This is due to better hydration of the cementitious fraction provided by moisture available from the slowly released reservoir of water absorbed within the pores of the lightweight aggregate. This process of internal curing is made possible when the moisture content of the aggregate, at the time of mixing, is in excess of that achieved in 1-day submersion. This fact was first documented in 1967 by Campbell and Tobin. Their tests confirmed that availability of absorbed moisture within the lightweight aggregate produced a more forgiving concrete that was less sensitive to poor field-curing conditions.

High cementitious concrete is vulnerable to self-desiccation and benefits significantly from the added internal moisture. This application is especially helpful for concrete containing high volumes of pozzolans that are sensitive to curing procedures. While improvements in long-term strength gain have been observed, the principal contribution of internal curing rests in the reduction of permeability that develops from a significant extension in the time of curing. In 1959 Powers et al., showed that extending the time of curing increased the volume of cementitious products formed, which caused the capillaries to become segmented and discontinuous.

13.4 Structural Efficiency – Lightweight Concrete in Structures

All products should optimize structural efficiency by improving the strength to weight ratio.

Buildings – A major reason lightweight concrete is used is for weight reduction which often enhances the functionality, architectural expression or constructability of a structure. In building this is achieved by thinner fire resistant slabs, longer spans, expressive roof design, taller buildings, additional floors added to existing structures and when building on locations with poor soil conditions. Weight reduction optimizes land use by affording a smaller footprint, which allows surrounding space to be more people friendly.

Less building materials are also used:

- The reduction in foundation loads may result in smaller footings, fewer piles, smaller pile caps, and less reinforcing;
- Reduced dead loads may result in smaller supporting members (decks, beams, girder, and piers)
- Reduced dead load will result in reduced inertial seismic forces;

Bridges - With bridges, this may allow a wider bridge deck (additional lanes) being placed on existing structural supports with minor or no modifications. Improved constructability may result in balanced cantilever bridge construction where lightweight concrete is used on one side of a pier and normalweight concrete used on the other to provide equal weight while accommodating a longer span on the lightweight side of the pier. This has permitted locating piers closer to land with significant reductions in cost. On bridge deck replacements or overlays the deck may be thicker to allow more cover over reinforcing or to provide better drainage without adding additional dead load to the structure. Lightweight concrete has been used to create longer bridge spans, thereby reducing the need for costly and aesthetically unacceptable piers.

Precast - Longer or larger precast members can be manufactured without increasing overall weight. This results in fewer columns or pier elements in a system that is easier to lift or erect with fewer joints or more elements per load when transporting. There are several documented cases where the savings in shipping cost far exceeded the increased cost of using lightweight concrete. At some precast plants each elements shipping cost is evaluated by computer to determine the optimum concrete density;

Marine - In marine application, increased allowable topside loads and the reduced draft resulting from the use of lightweight concrete may permit easier movement out of dry docks and through shallow shipping channels.

Specified density concrete - Specified density concrete is becoming increasingly used to enhance design flexibility and project economics. Specified density is defined as concrete containing limited amounts of lightweight aggregate that result in equilibrium concrete densities greater than 120 lb/ft³ (1920 kg/m³) but less than concrete composed entirely of normalweight aggregates. The increasing usage of specified density concrete is driven by engineers' decisions to optimize the concrete density to improve structural efficiency (strength to density ratio), to reduce concrete product transportation and construction costs, and to enhance the hydration of high cementitious concrete with very low *w/cm* (ACI 213R-03).

Insulation - The low thermal conductivity of lightweight concrete provides significantly better insulating qualities for thermally sensitive applications such as cryogenic applications or high temperature petroleum storage structures.

13.5 Construction Efficiency - Environmental and Ergonomic Impact

Transportation — Construction requires transportation! Therefore, there is a direct correlation between cost as well as the environmental impact. Transportation costs are directly related to the weight of concrete products, demonstrating a significant economic advantage when using lightweight concrete. The range of products includes large structural members (girders, beams, walls, hollow-core panels, double tees) to smaller consumer products (precast stair steps, fireplace logs, wall board, and imitation stone). Two trucking studies conducted at a U.S. precast plant are shown in Table 13.1. These studies demonstrated that the transportation cost savings were seven times more than the additional cost of lightweight aggregate. Savings vary with the size and mass of the product and are most significant for the smaller consumer-type products. For example, one manufacturer of lightweight concrete wallboard has shipped products to all 48 mainland states from one manufacturing facility.

Fewer trucks in congested cities are not only an environmental necessity but will also generate fewer public complaints. The potential for lower costs is possible when shipping by rail or barge but is most often realized in trucking where highway loadings are posted.

Table 13.1 Analysis of Shipping Costs of Concrete Products *		
	Project Example Number 1	**Project Example Number 2**
Shipping Cost per Truck Load	**$ 1,100**	**$ 1,339**
Number of Loads Required		
Normalweight	**431**	**87**
Lightweight	**287**	**66**
Reduction in Truck Loads:	**144**	**21**
Transportation Savings		
Shipping Cost per Load	**$ 1,100**	**$ 1,339**
Reduction in Truck Loads	**x 144**	**x 21**
Transportation Savings:	**$ 158,400**	**$ 28,119**
Profit Impact		
Transportation Savings	**$ 158,400**	**$ 28,119**
Less: Premium Cost of lightweight concrete	**- 17,245**	**- 3,799**
Transportation Cost Savings by using lightweight concrete	**$ 141,155**	**$ 24,320**

*Courtesy of Big River Industries, Inc.

With ready-mix concrete up to 25% more, lightweight concrete can be delivered to the job site per truck load than with conventional concrete. This also translates into fewer trucks on the roads and around congested construction sites. Also see example in Table 13.3 Lightweight Concrete Masonry Units Saves Truck Miles.

Sustainability of the Workforce - Ergonomics – Less weight makes concrete labor friendly. The best example of lightweight concrete and ergonomics is with concrete masonry. The Center for Infrastructure Research, University of Nebraska at Lincoln reported that long-term problems stem from heavyweight concrete masonry units. "Concrete masonry is a dominant material in wall construction. Over $10 billion worth of masonry walls are constructed in the United States every year. However, the industry is facing a shortage of qualified masons, and the average age of active masons has been gradually increasing due, in part, to the hard work they have to do in lifting heavy concrete masonry units. The load of lifting these blocks, day after day, can make drudgery out of a day's work for a mason, especially after many years. **Some masons must retire early due to the heavy lifting, and many masons experience crippling back and shoulder injuries before retirement".** This continual loss of skilled labor is expensive to replace and may ultimately make masonry non-competitive.

By reducing the weight of concrete masonry and other concrete products that must be physically handled by labor we enhance sustainability to our workforce. It is common knowledge that lighter components have a positive effect on constructability, for example (ESCSI info sheet 3650.3, 1996):

- At the same strength, lightweight concrete masonry units are up to 40% lighter than traditional concrete masonry units. Less weight minimizes the physical demands on masons and equipment, resulting in fewer injuries and workers' compensation claims. Repeatedly lifting less weight also extends a mason's career, and allows women and men to work efficiently.
- Concrete masonry units that weigh less will increase mason productivity up to 21% on 8x8x16" units, and 55% on 12x8x16" units. Increase productivity means earlier completion and lower overhead costs. Even though a mason will lay approximately 20% more wall area in a year, the mason still lifts 15% less weight (about 94 less tons per year).
- Less weight extends equipment life because lighter loads mean less wear and tear and helps insure safer scaffolding and worker platforms. Less weight means it is easier to meet OSHA weight requirements.

13.6 Structural Performance – How does ESCS lightweight aggregate affect the overall performance of the structure?

Fire resistance - Lightweight concrete is more fire resistant than ordinary normalweight concrete because of its lower thermal conductivity, lower coefficient of thermal expansion, and the inherent fire stability of an aggregate already heated to over 2000 ºF (1100 ºC); As reported in ACI 216 "Standard Method for Determining Fire Resistance of Concrete and Masonry Construction Assemblies", when slab thickness is determined by fire resistance and not by structural criteria (joists, waffle slabs e.g.), the superior performance of lightweight concrete, will reduce the thickness of slabs resulting in significantly lower concrete volumes.

Service life of the structure - The first known use of lightweight concrete dates back over 2000 years. There are several lightweight concrete structures in the Mediterranean region, but the three most notable structures were built during the early Roman Empire and include the Port of Cosa, the Pantheon Dome, and the Coliseum.

The Port of Cosa, built about 273 B.C., used lightweight concrete made from natural volcanic materials. These early builders learned that expanded aggregates were better suited for marine facilities than the locally available beach sand and gravel. They went 25 miles (40 km) to the northeast to quarry volcanic aggregates at the Volcine complex for use in the harbor at Cosa. Broken shards of calcined clay vases were also used in the piers....the first usage of manufactured aggregate. This harbor is on the west coast of Italy and consists of a series of four piers (~ 13 ft [4 m] cubes) extending out into the sea. For two millennia they have withstood the forces of nature with only surface abrasion. They only became obsolete because of siltation of the harbor.

The Pantheon, finished in 27 B.C., incorporates concrete varying in density from bottom to top of the dome. Roman engineers had sufficient confidence in lightweight concrete to build a dome whose diameter of 142 ft (43.3 m) was not exceeded for more than nineteen hundred years. The structure is in excellent condition and is still being used to this day for spiritual purposes.

The Coliseum, built in 75 to 80 A.D., is a gigantic amphitheater with a seating capacity of 50,000 spectators. The foundations were cast as lightweight concrete using crushed volcanic lava. The walls were made using porous, crushed-brick aggregate. The vaults and spaces between the walls were constructed using porous-tufa cut stone. After the fall of the Roman Empire, lightweight concrete use was limited until the twentieth century when expanded shale, clay and slate lightweight aggregate became available for commercial use (ESCSI 1971)
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While it is clearly understood that the terms high strength and high performance are not synonymous, we may consider the first modern use of high-performance concrete to be when the American Emergency Fleet Corporation built lightweight concrete ships (1917-1920) with specified compressive strengths of 5000 psi (35 MPa) was obtained with a unit weight of 110 lb/ft^3 (1760 kg/m^3) or less, using rotary kiln produced expanded shale and clay aggregate. Commercial normalweight concrete strengths of that time were approximately 2500 psi (17 MPa).

In energy-related floating offshore concrete structures, great efficiencies are achieved when a lower density material is used. A 25% reduction of mass in air will result in a 50 % reduction when submerged. Because of this, the oil and gas industry recognized that lightweight concrete could be used to good advantage in its floating structures as well as structures built in a graving dock and then floated to the production site and bottom founded.

Several hundred bridges have incorporated lightweight concrete into decks, beams, girders, or piers. Transportation engineers generally specify higher concrete strengths primarily to ensure high-quality mortar fractions (high compressive strength combined with high air content) that will minimize maintenance. Thousands of bridges in the United States are functionally obsolete with unacceptably low load capacity or an insufficient number of traffic lanes. Structural lightweight concrete has played a major roll in bringing these structures up to modern compliance in an environmentally responsible way.

13.7 How does SLA fit into the LEED™ Green Building Rating System?

The use of SLA in building designs contributes toward LEED Green Building certification credits. The Leadership in Energy and Environmental Design (LEED) system was designed by the United States Green Building Council (USGBC) to evaluate the influence of building design and construction on the environment.

The versatility of SLA allows it to be used in several different construction applications that apply to diverse areas of the LEED System. The following LEED credits are areas where SLA can contribute to achieving the intended goals.

LEED-NC Rating System Summary (Version 2.1)

Category	Available Points	Points Where SLA Can Contribute
Sustainable Sites	14	4
Water Efficiency	5	3
Energy & Atmosphere	17	1+ *(see note below)*
Materials & Resources	13	5
Indoor Environmental Quality	15	1
Innovation & Design	5	1
Total Possible Points	**69**	**15+**

Note: *1-10 points can be awarded for energy cost savings of 15%-60% for new buildings and 5%-50% for existing buildings. SLA will improve the thermal performance of building materials and contribute toward obtaining these credits.*

Sustainable Site Credit 6.1
Stormwater Management: Rate and Quantity
Limit disruption and pollution of natural water flows by managing stormwater runoff.

SLA can be used as part of a designed plantings scheme to reduce the amount of stormwater runoff. SLA can be incorporated into an engineered soil that will support healthy plant growth and allow free draining of soils. The use of SLA in a structural soil application will allow access by heavy emergency vehicles to the edges of buildings while still supporting vegetation.

Sustainable Site Credit 6.2
Stormwater Management: Treatment
Limit disruption of natural water flows by eliminating stormwater runoff, increasing on site infiltration and eliminating contaminates.

SLA can be used to construct, vegetated filter strips, and bioswales to treat the site's stormwater. The pores within SLA provide an environment suitable for beneficial microbial action that will help to filter stormwater.

Sustainable Site Credit 7.1
Heat Island Effect: Non-Roof
Reduce heat islands (thermal gradient differences between developed and undeveloped areas) to minimize impact on microclimate and human wildlife habitat.

SLA can be incorporated into the engineered soil to allow plantings in and around paved areas. The pores within SLA provide air to the soil mixture and will minimize compaction of the planting beds.

Sustainable Site Credit 7.2
Heat Islands Effect: Roof
Reduce heat islands (thermal gradient differences between developed and undeveloped areas) to minimize impact on microclimate and human wildlife habitat.

SLA has been used for both intensive and extensive rooftop gardens on a number of projects. SLA provides a lightweight component of soil blends that incorporate air into the soil mixture as well as providing tiny reservoirs that hold water and soluble nutrients for the vegetation to absorb. SLA enhances the performance of green spaces there by helping to reduce heat absorption into the structure and in some cases provide a usable recreation area.

Water Efficiency Credit 1.1 & 1.2
Water Efficient Landscaping:
Credit 1.1 - Reduce by 50%,
Credit 1.2 - No Portable Use or No Irrigation
Limit or eliminate the use of potable water for landscape irrigation.

The porous, cellular nature of SLA helps manage water use, reduce compaction, increase soil porosity, and maintain soil temperature. SLA acts as a moisture flywheel absorbing moisture during wet periods and slowly releasing it along with any soluble nutrients for plant use during dry periods.

Water Efficiency Credit 2
Innovative Wastewater Technologies
Reduce generation of wastewater and portable water demand, while increasing the local aquifer recharge.

SLA can be used as part of an on-site sewage treatment system. SLA has been used to improve the efficiencies of septic systems. Because of SLA's porous cellular structure, the aggregate particles provide an environment suitable for beneficial microbial action resulting in enhanced waste decomposition and wastewater filtration . SLA has also been used in living machines that process the generated waste stream through the use of innovative natural environments that filter and digest wastes in many different stages. SLA has shown excellent removal capacities for reduction of phosphorus.

Energy & Atmosphere Prerequisite 2
Minimum Energy Performance
Establish the minimum level of energy efficiency for the base building and systems.

The thermal efficiency of building components manufactured with SLA can maximize the energy performance of the building while still allowing design flexibility. This improvement in thermal performance will help the building design to meet the ASHRAE/IESNA 90.1-1999 requirements.

Energy & Atmosphere Credit 1
Optimize Energy Performance
Achieve increasing levels of energy performance above the prerequisite standard to reduce environmental impacts associated with excessive energy use.

Lightweight block and lightweight structural concrete provide higher insulating values than normal density block and structural concrete while still having the benefits of a mass wall. Lightweight concrete building components optimize the combination of R-values, thermal mass, and low thermal bridging to create a superior building system. The higher thermal resistance provided by substituting SLA in place of normal weight aggregates will improve the insulating capabilities of building components. The optimized density will provide a structural thermally efficient wall system that lowers the overall energy consumption and helps to shift the peak cooling and heating loads to off-peak times.

Table 13.2

Effect of Density on Thermal Performance of Concrete Masonry Units R-Values For 8 in. (203 mm) Concrete Masonry Walls, hr·ft²·°F/Btu						
Construction	Density of concrete (pcf)	Cores Empty	Loose-fill insulation		Polyurethane foamed insulation	Solid grouted
			Perlite	Vermiculite		
Exposed block, both sides	85	2.5	7.1	6.6	8.0	2.0
	95	2.4	6.1	5.7	6.7	1.8
	105	2.2	5.2	4.9	5.6	1.7
	115	2.1	4.4	4.3	4.7	1.6
	125	2.0	3.8	3.7	4.0	1.5
	135	1.9	3.3	3.2	3.4	1.5

Source: National Concrete Masonry Association NCMA TEK 6-2A: R-Values for Single Wythe Concrete Masonry Walls

Materials & Resources Credits 1.1, 1.2, & 1.3
Building Reuse:
Credit 1.1 - Maintain 75% of Existing Walls, Floors and Roof
Credit 1.2 - Maintain 100% of Existing Walls, Floors and Roof
Credit 1.3 - Maintain 100% of Shell/Structure and 50% of Non-shell/Non-Structure

Extend the life cycle of existing building stock, conserve resources, retain cultural resources, reduce waste and reduce environmental impacts of new buildings as they relate to materials manufacturing and transport.

Lightweight concrete masonry units and lightweight concrete have been utilized in the reuse of numerous buildings. Lightweight building components utilizing SLA have lighter weight while still being structural. These lightweight components allow buildings to be redesigned, improved, and retrofitted while still using original foundations and structural members.

Materials & Resources Credit 5.1
Regional Materials: 20% Manufactured Regionally

Increase demand for building materials and products that are extracted and manufactured within the region, thereby supporting the regional economy and reducing the environmental impacts resulting from transportation.

Building components and soil mixtures with SLA are manufactured at numerous facilities in close proximity to almost every building site (block producers, ready mix suppliers, precast producers and soil blenders) are close to most jobsites.

Materials & Resources Credit 5.2
Regional Materials: 50% Extracted Regionally
Increase demand for building materials and products that are extracted and manufactured within the region, thereby supporting the regional economy and reducing the environmental impacts resulting from transportation.

SLA is manufactured at facilities within a 500-mile radius from virtually all locations in the continental United States.

Indoor Environmental Quality Credit 7.1
Thermal Comfort: Compliance with
ASHRAE 55-1992
Provide a thermally comfortable environment that supports the productivity and well being of building occupants.
Improving the thermal performance of the building components used to construct a structure will help to contribute to a comfortable environment to live and work in.

Innovation & Design Process Credit 1
Innovation in Design
To provide design teams and projects the opportunity to be awarded points for exceptional performance above the requirements set by the LEED Green Building Rating System and/or innovative performance in Green Building categories not specifically addressed by the LEED Green Building Rating System.

The use of building components manufactured with SLA will allow more building products to be carried on the same truck when compared to heavy building products. This will decrease the truckloads required to deliver the same volume of product. Less trucks on the road reduces the pollutants emitted from transportation as well as reducing traffic congestion. Switching from heavyweight concrete masonry units to lightweight concrete masonry units saves truck miles as illustrated below.

Table 13.3 Lightweight Concrete Masonry Units Saves Truck Miles

ITEM	Normalweight 135 PCF	Lightweight 93 PCF	Difference LW vs NW
Quantity of 8"on Job	100,000	100,000	0
Weight of CMU (lbs)	38	26	12 pounds less
Truck capacity (lbs)	32,000	32,000	0
Units per load	842	1,230	388 more block per load
Wall area per load (sq ft)	748	1,093	345 more sq ft of wall per load
Number of truckloads required	119	82	37 less truckloads
Distance to job (miles)	100	100	0
Total miles traveled	5,950	4,100	1,850 less truck miles traveled
Cost @ $1.85 per mile	$ 11,900	$8,200	$3,700 savings in trucking cost
Delivery cost per block	$0.12	$0.08	$0.04 savings per block

13.8 Economics of Sustainability

The use of any building material is predicated on cost, functionality, aesthetics, or a combination of these. The "politically correct" minimum first cost methodology of owners, designers and public officials around the world has contributed to a non-sustainable system. Decisions based on first cost ignore life long maintenance, rehabitation and operating cost. A stronger-faster-is-better attitude has unfortunately lead to an unintended consequence, a high level of widespread early age cracking. Life cycle costing is the only way to evaluate the sustainability of a project.

The cost of lightweight concrete per cubic yard (cubic meter) is usually higher than a comparable unit of ordinary concrete. The following example is a typical comparison of unit cost between lightweight and normalweight concrete on a bridge project.

Assume the in-place cost of a typical short span bridge may vary from 50 to 200 $\$/ft^2$ (540 to 2150$\$/m^2$).
If the average thickness of the deck was 8 in. (200 mm) then one cubic yard (m^3) of concrete would yield approximately 40 ft^2/yd^3 ($5m^2/m^3$) of deck area.
Using lightweight concrete with a premium in the range of 20 $\$/yd^3$ (26 $\$/m^3$) over normalweight concrete would result in: 20 $\$/yd^3$/40 ft^2/yd^3 = 0.50 $\$/ft^2$ (5 $\$/m^2$) or generally less than a 1% increase (reference ACI 213).
This increase is more than offset by the cost savings in reduced concrete and reinforcing in girders, piers, footings, as well as other benefits covered earlier.

Overall Environmental Importance

Very early in the conceptual design an evaluation of how the structure interfaces with its environment needs to be made. Structures using these products must blend with and enhance the sustainability and the overall quality of life.

Energy consumption - Edward Mazria, author of the 1979 book “The Passive Solar Energy Book” claims the conventional wisdom of his profession, architecture, is dangerously out of touch with reality. Mazria reorganized the existing data of the U.S. Energy Consumption by sector and exposed architecture as both the problem and potential solution for global warming (Metropolis, Oct. 2003). The Metropolis article points out by “combining the energy required to run residential, commercial, and industrial buildings along with the embodied energy of industry – provided materials like carpet, title and hardware, architecture accounts for 48% of energy consumption. Total energy consumption as reported is shown in the following table:

Table 13.4

Sector	U.S. Energy Consumption published data	U.S. Energy consumption re-arranged by Edward Mazria
Industry	35%	25% *
Residential	21%	*
Commercial	17%	*
Architectural	—	48%
Transportation	27%	27%
Total	100%	100%

* All or a portion included in Architecture.
(Source Metropolis, October 2003)

When viewed from Mazria’s architecture prospective, architecture is shown to be the primary CO_2 emitter. This points out the pressing need for widespread change in the way buildings are designed. Buildings and structures need to be more energy efficient and engage environmental issues.

U.S. CO_2 Emissions By Sector

Table 13.5 U.S. CO_2 Emissions by Sector

Sector	1950 mmt (million metric tons)	2000 mmt	% Increase
Industry *	215	330	53
Architecture	275	720	162
Transportation	180	520	189

***** U.S. CO_2 Emission have been essentially constant at about 330 mmt since 1970 (Source Metropolis, October 2003)

Energy Performance

The embodied energy to manufacture rotary kiln structural lightweight aggregate includes mining, manufacturing, and transporting the material to the jobsite, soil blender, or building product manufacturer. The cost of this embodied energy is often paid back in a very short period of time, because of the increased thermal performance, lower transportation costs, and reduction of labor costs associated with the building elements. For example the following embodied energy payback using expanded shale, clay and slate in concrete masonry is less than one year.

Energy savings result from using ESCS aggregate in a typical lightweight concrete masonry unit, compared to using heavy normalweight aggregate for the same concrete masonry unit. These calculations assume the masonry is used in single wythe integrally insulated exterior building walls, which is a typical application.

The ESCS production BTU input and 1350 lb cu yd average density is per the Life Cycle Inventory analysis of ESCS performed for the Expanded Shale, Clay and Slate Institute by CTL (Construction Technology Laboratories). Reference their February 17, 2000 report.

$$\frac{2{,}300{,}000\left(\frac{Btu}{Ton\,\text{ESCS}}\right)}{2000\frac{\text{lb}}{\text{Ton}}} = 1150\frac{Btu}{lb\,\text{ESCS}}$$

A typical mix design for 8" lightweight CMU meeting ESCSI's SmartWall® specification density (93 pcf) and strength (2500 psi) is:

Cement	176 lb	
Fly Ash	59 lb	
ESCS Aggregate	1135 lb	(22.7 loose cu ft @ 50 pcf)
Sand Aggregate	430 lb	(4.3 loose cu ft @ 100 pcf)
Water	112 lb	
Totals	1913 lb	(27.0 loose cu ft)

This mix is expected to yield 75 8" CMU with a wet weight of 25.5 lb and a cured weight of 24.0 lb. Each CMU has 15.1 lb of ESCS aggregate in it based on the expected yield.

Calculate the Btu's needed to produce the lightweight aggregate in each block:

$$1150\frac{Btu}{lb\,\text{ESCS}}\,x15.1\frac{lb\,\text{ESCS}}{Block}=17{,}365\frac{Btu}{Block}$$

The energy saved in use in an exterior wall is documented in ESCSI Information Sheet #3530 for a "big box" building located in Omaha Nebraska. The difference in wall conductivity values between a 93 pcf lightweight CMU and a heavy normalweight 135 pcf CMU is shown as 0.157; using this value iunthe calculations:

$$0.157\frac{Btu}{hr\cdot ft^{2}\cdot{}^{o}F}\,x\,6201\frac{{}^{o}F\cdot Days}{Year}\,x\,24\frac{\text{Hr}}{\text{Day}}=23{,}365\frac{Btu}{Ft^{2}\cdot Yr}$$

$$23{,}365\frac{Btu}{Ft^{2}\cdot Yr}\,x\,\frac{128}{144}\frac{In^{2}/Block}{In^{2}/Ft^{2}}=20{,}769\frac{Btu}{Block\cdot Yr}$$

Calculate the payback period by dividing the one time energy input to the ESCS aggregate in the lightweight CMU by the annual energy savings per block:

$$\frac{17{,}365\frac{Btu}{Block}}{20{,}769\frac{Btu}{Block\cdot Yr}}=0.84year$$

This sample is on the conservative side as it does not include added savings in trucking cost, handling, lower dead loads etc. In other words life cycle energy savings realized from using ESCS will help to conserve valuable natural resources for future generations.

Thermal performance - Lowering the concrete density increases thermal resistance. For example concrete at 90 lb/ft^3 has an R value of 0.26/inch where the R value for 135 lb/ft^3 concrete is approximately .10/inch. In other words the 90 lb/ft^3 concrete have a 260% better insulation factor then the 135 lb/ft^3 material (ESCSI info sheet 3201, 1999).

Henderson Engineering, Inc., Kansas City, MO, performed an energy cost study on a "big box retail" building for the Expanded Shale, Clay & Slate Institute to determine how lightweight concrete masonry at 90 lb/ft^3 affected the LEED category EA1 when compared to normalweight concrete masonry at 135 lb/ft^3. Several locations were evaluated with results for Omaha, NE (a central location) listed as follows:

- Heating peak loads for exterior walls was 44% less.
- Cooling peak loads for exterior walls was 51% less.
- Total building heating peak load was 12% less.
- Total building cooling peak load was 2% less.
- Total building annual energy consumption was 2.2% less.

These savings translate into 5.5 cents per block per year. That savings is significant and extends over the life of the structure. This life cycle savings per block is many, many times greater than the potential higher first cost of the block. The peak load savings allow for smaller, more economical HVAC equipment to be used in many cases. This in turn lowers initial equipment cost and weight, and reduces peak demand on utility infrastructure. The annual energy consumption savings was calculated using flat rate energy cost. Additional benefits will result when using off-peak utility rates that are a consequence of longer time lags made possible with lightweight concrete.

Embodied energy - It is well documented that the total embodied energy to build a building is only 1 to 3% of the total occupant energy used by that building over its useful life (Construction Technology Laboratories report project no. 180028 conducted for ESCSI 2001). In light of the facts that approximately 97 to 99% of the energy used throughout the building life cycle is primarily a function of climate and occupant behavior, it becomes obvious that our biggest energy resource is efficiency.

Performance - From a performance perspective, concrete has room for improvement. There are many examples of concrete deteriorating after 10, 20 or 30 years in service. This is unacceptable when compared to numerous examples of concrete structures lasting well over 100 years and in some cases 2000 years. Poor performing concrete has frequently resulted from inadequate specification and/or improper designs for the intended use. The entire concrete community (owner, designer, material supplier, concrete manufacturer, and contractor) has fallen short by not implementing and transferring the currently available knowledge needed to insure that quality concrete is specified and constructed. Raising the minimum requirements in building codes and ACI and ASTM standards may be required to meet sustainable development demands and lower life cycle cost.

Society must now define and require a profoundly extended service life from its structures. Are 100, 300 or 1000 year design lives appropriate? Its becoming very evident that economic and environmental burdens will not allow future generations to replace structures (utility lines, bridges, roads, buildings, etc) every 20, 30 or 50 years. Many of our structures are designed as essentially throw away structures. To meet the challenges of sustainable development the concrete industry needs to recognize our global responsibility and offer longer lasting products that are properly specified, designed and constructed.

Life Cycle Cost Performance

The long-term value of any building material is predicated on a combination of cost, durability, functionality, and aesthetics. Life cycle costing is the only way to truly evaluate the performance and long-term sustainability of a material or building project.

In structures, any increased up-front cost of components manufactured with SLA is more than offset by the cost savings in the following areas: labor, lower dead loads, better fire resistance resulting in reduced concrete thickness, less reinforcing required in building frames, girders, piers, and footings. Long-term heating and cooling costs will also be reduced due to the higher insulating properties and overall superior thermal performance of the building.

In site development, reduced water consumption, reduced stormwater runoff, improved on-site wastewater treatment and better plant quality provide for positive life cycle cost performance.

13.9 The Holistic Picture

Rotary kiln produced structural lightweight aggregate is an environmentally friendly product with unique features that allow it to be used in a multitude of applications that contribute to the sustainability of the site and structure.

Examples have shown where the use of lightweight aggregate in concrete has saved materials, labor and transportation cost, as well as improving the performance and service life of concrete. In addition, it has shown how using lightweight aggregate can lower the overall energy consumption of structures throughout their useful lives. These benefits all fit into the green building movement and help projects become LEED certified. The use of lightweight aggregate often lowers initial construction cost and most importantly, significantly lowers the life-cycle cost of the structure.

When viewed from an overall holistic perspective, the utilization of SLA is a small but important step forward. For the successful achievement of truly sustainable development, a fundamental shift in attitudes, belief systems and conscious behavior must take place. Considering the fact that architecture (building performance) accounts for a major part of total U.S. energy consumption, initial cost should no longer be the sole determining criteria when evaluating the usefulness of a product or structure. All construction materials must be evaluated by life cycle assessment. This is the only way to determine the long-term impact of a product or structure. To develop a sustainable world we must shift from our current short-term ways and attitudes, to a long-term, holistic mind-set that recognizes performance and the interdependence of all life.

The biggest hurdle in creating a sustainable social, economical and political society is overcoming the belief that "it can't be done". Many people believe that any significant move toward sustainable development will result in a disruption of our current system. We do not share this position. We believe a sustainable way of life can be immediately implemented in a positive, responsible and practical way. If everyone involved in the building industry especially Architects and engineers, started to create energy efficient building designs, major positive environmental changes would take place.

The perception that fast track construction saves time and money needs to be re-evaluated. There are numerous examples of the old adage, "Haste makes waste," being true with Fast-Track. From a long-term sustainable development perspective, in some cases fast-track attitude may be counter productive and result in non-sustainable construction practices and poor performing buildings and structures.

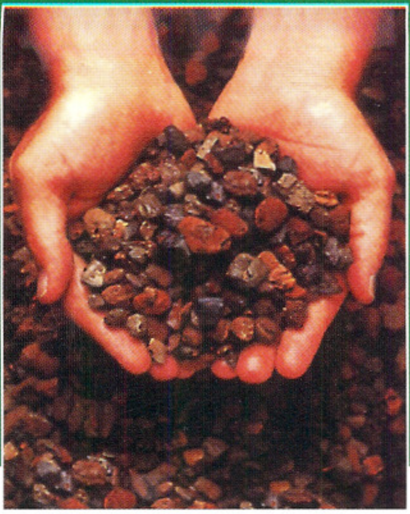
As stated earlier the primary objective of truly achieving sustainability is to change beliefs and attitudes. This requires concern for long-term performance with minimal maintenance and energy requirement in our designs, as well as efficiency and responsibility in our manufacturing. There are many changes that can be accomplished in the present that will yield major positive results for humanity now and in the future. We have listed just a few improvements that affect the concrete community.

AFTER ALL, SUSTAINABILITY IS JUST GOOD DESIGN AND COMMON SENSE!

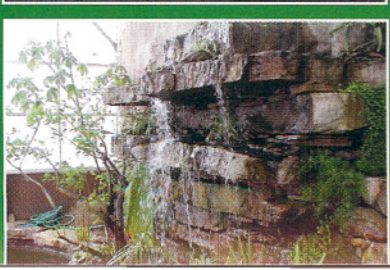
13A

ESCSI Publication 7700.0

"Structural Lightweight Aggregates' Holistic Contribution to Sustainable Development"

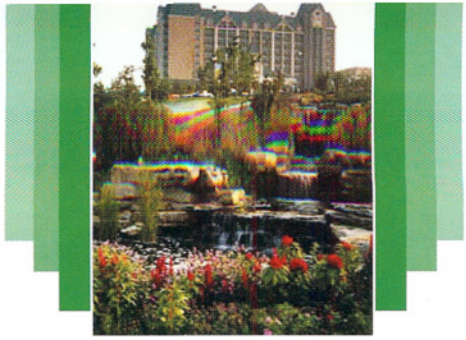


Structural Lightweight Aggregates' Holistic Contribution to Sustainable Development



ESCSI

ROTARY KILN PRODUCED
STRUCTURAL LIGHTWEIGHT AGGREGATE



Structural Lightweight Aggregates' Holistic Contribution to Sustainable Development

Our Commitment to Sustainable Development

The Expanded Shale, Clay and Slate Institute (ESCSI) and its member companies are committed to the long-term performance of our products and the sustainable development of the building industry. Innovative, practical and responsible designs, combined with realistic construction practices, will contribute to the establishment of a vibrant, sustainable society. The use of lightweight aggregate will contribute significantly to sustainable development and promote the ability of future generations to meet their own needs.

Structural lightweight aggregate (SLA) has been successfully used for well over two millennia. It has had widespread use for the past eighty years. This track record of proven performance has demonstrated how structural lightweight aggregate contributes to sustainable development by conserving energy, lowering transportation requirements, maximizing structural efficiency and increasing concrete service life. The use of lightweight aggregate in site development assists designers in addressing the important issue of storm water management with on site treatment. SLA can help to reduce heat island effects by amending soil to improve landscaping and promoting the use of "green roofs."

What is Rotary Kiln Produced Structural Lightweight Aggregate?

SLA is a ceramic material produced by expanding and vitrifying select shales, clays, and slates in a rotary kiln. The process produces a high quality ceramic aggregate that is structurally strong, physically stable, durable, environmentally inert, light in weight, and highly insulative. It is a natural, non-toxic, absorptive aggregate that is dimensionally stable and will not degrade over time.

How does SLA fit into the LEED™ Green Building Rating System?

The use of SLA in building designs contributes toward LEED Green Building certification credits. The Leadership in Energy and Environmental Design (LEED) system was designed by the United States Green Building Council (USGBC) to evaluate the influence of building design and construction on the environment.

SLA is a highly versatile material with many uses. Its varied applications apply to diverse areas of the LEED System. Listed below are SLA's benefits and their relation to the six basic areas of concentration outlined in the LEED rating system.

LEED Rating System Summary (Version 2.1)

Category	Available Points	Points Where SLA Can Contribute
Sustainable Sites	14	4
Water Efficiency	5	3
Energy & Atmosphere	17	1+ (*see note below*)
Materials & Resources	13	5
Indoor Environmental Quality	15	1
Innovation & Design	5	1
Total Possible Points	**69**	**15+**

Note: *1-10 points can be awarded for energy cost savings of 15%-60% for new buildings and 5%-50% for existing buildings. SLA will improve the thermal performance of building materials and contribute toward obtaining these credits.*

Sustainable Sites

Limits storm water runoff – allows free draining of soils;

Structural soils – the strong, inert, ceramic nature of SLA resists degradation and will support the weight of vehicles while still allowing a healthy root system.

Bioswales – will help to direct runoff and filter contaminates;

Vegetative filter strips – supports plant growth and filters solids; SLA has been used extensively in site development and in horticultural applications for the promotion of plant growth;

Constructed wetlands – superb phosphorus removal properties;

Rooftop gardens – used in both intensive and extensive applications; blended into soil, SLA's absorptive, porous, ceramic characteristics provide critical soil aeration necessary for plant growth and survival; its lighter weight reduces deadloads on rooftop structures.

Water Efficiencies

Drought resistant plantings – allows reduction of potable water use; SLA's porous characteristics serve as a moisture buffer and offer a degree of drought resistance;

On-site sewage treatment – supports beneficial aerobic microbial action for waste decomposition and wastewater filtration systems.

Energy and Atmosphere

Low thermal conductivity – Lightweight concrete building components will increase the thermal resistance of the structural envelope;

Mass wall construction – thermal lag shifts the peak heating/cooling loads to off peak times;

Low thermal bridging – minimizes heat flow bridging around insulation products.

Materials and Resources

Lightweight concrete building components – may be used to retrofit structures with minimal impact on foundations;

Products made with SLA are manufactured locally – producers in close proximity to jobsites;

SLA extracted regionally – virtually all of United States within 500 miles radius of manufacturing location. Because of its lower weight SLA is often shipped longer distances economically.

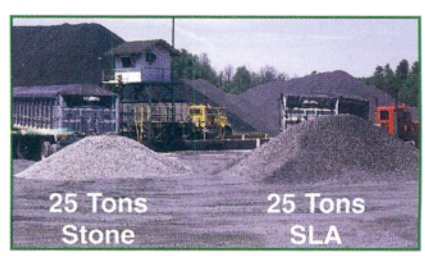
Indoor Environmental Quality

Better thermal performance – will contribute to a thermally comfortable environment;

Not a source of food for mold – will not contribute to sick building syndrome.

Innovation & Design Process

Lightweight building components – requires fewer truckloads of material for same application. This also reduces traffic congestion and air pollution.



Life Cycle Cost Performance

The long term value of any building material is predicated on a combination of cost, durability, functionality, and aesthetics. Life cycle costing is the only way to evaluate the performance and long-term sustainability of a material or building project. Any increased up-front cost of components manufactured with SLA is more than offset by the cost savings in the following areas: labor, lower dead loads, better fire resistance resulting in reduced concrete thickness, less reinforcing required in building frames, girders, piers, and footings. Long-term heating and cooling costs will be reduced due to the higher insulating properties and overall superior thermal performance of the building.

Energy Performance

The embodied energy to make SLA includes mining, manufacturing, and transporting the material to the jobsite or building product manufacturer. The cost of this embodied energy is often paid back in a very short period of time, because of the increased thermal performance and lower transportation and labor cost associated with the building elements. Life cycle energy savings realized from using SLA will help to conserve valuable natural resources for future generations.

The Holistic Picture

Rotary kiln produced structural lightweight aggregate is an environmentally friendly product that saves material, labor and transportation cost, as well as improves the functionality and service life of concrete. Additionally, using lightweight aggregate will lower the overall energy consumption of structures thereby reducing the associated life cycle costs throughout the structure's useful life. These benefits support sustainable development and contribute to projects becoming LEED certified.

When viewed from an overall perspective, the utilization of SLA is a small but important step forward. The lightweight aggregate industry acknowledges that for the successful achievement of truly sustainable development, a fundamental shift in attitudes, belief systems and conscious behavior must take place. Considering the fact that architecture (building performance) accounts for a major part of total U.S. energy consumption, initial cost should no longer be the sole determining criteria when evaluating the usefulness of a product or structure. All construction materials must be evaluated from a total life cycle assessment. This is the only way to determine the total impact of a product or structure. To develop a sustainable world we must shift from our current short-term ways and attitudes, to a long-term, holistic mind-set that recognizes performance and the interdependence of all life.

Material Supplier

EXPANDED SHALE, CLAY AND SLATE INSTITUTE
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Publication 7700
June 2004

13B

ESCSI Publication 8621 "SoilMatrix Gives Your Greenroof the Lightweight Advantage"

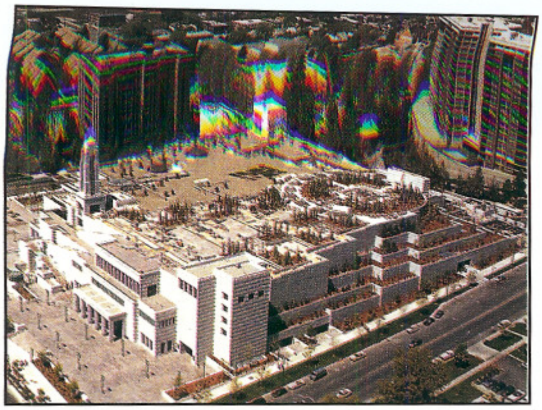
GREENROOF

SOILMatrix™

GIVES YOUR GREENROOF THE LIGHTWEIGHT ADVANTAGE

(Above) Intensive Roof Garden
North Park 400, Atlanta GA
Installed 1997; Pictured 2002

(Inset) Aerial view of North Park roof after installation in 1997



7-acre rooftop garden atop LDS Conference Center in Salt Lake City, UT.

Perimeter planting on roof of LDS Conference Center in Salt Lake City, UT.

Extensive greenroof garden, City Hall, Atlanta, GA, 2004

SOILMatrix installed by blowing equipment atop six-story Atlanta City Hall

SOILMatrix™

GIVES YOUR GREENROOF THE LIGHTWEIGHT ADVANTAGE

SOILMatrix has a long history of success in horticultural applications all over the world. It is marketed under various trade names and has established itself as the standard for creating planting media for rooftop gardens. This track record of proven performance demonstrates how SOILMatrix, at about 50% of the weight of natural planting media, contributes to sustainable development by conserving energy, reducing trucking requirements and minimizing the impact on structures. The use of this environmentally friendly ceramic material in green-roof design helps address important issues such as managing storm water runoff, improving water quality, reducing urban heat, conserving energy, lowering dead load and increasing green space.

SOILMatrix being installed at LDS Conference Center

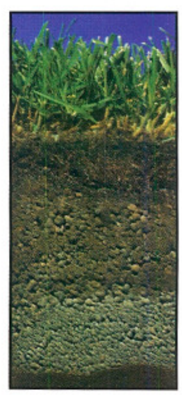
Greenroof Planting Media

One of the most important components to both extensive and intensive greenroof systems is a quality planting medium. Because of the complex nature of greenroof construction and the difficulties of access after completion, the planting media must be able to support and sustain plants for the duration of the intended life span of the roof. A well-designed planting medium will have the following physical characteristics:

- **Be free of silts and clays that could clog the filter fabric;**
- **Have permanent internal aeration even after several years of consolidation;**
- **Insure adequate drainage;**
- **Insure stable root support;**
- **Not degrade, breakdown or shrink in volume over time.**

SOILMatrix is the environmentally friendly answer that provides a long-term solution to the above complex design requirements.

Besides exceeding all the requirements of an ideal planting medium, SOILMatrix provides additional important benefits. Its reduced weight can often accommodate structural design requirements; yet it is heavy enough to avoid loss caused by excessive wind or water. Its angular, stable and



SOILMatrix planting medium promotes healthy root development.

porous ceramic nature ensures an adequate supply of air to enable plants to be established quickly and develop healthy root systems. Ample aeration increases the insulative properties of the planting media and helps reduce energy consumption as well as lessen the urban heat island effect. Overall project costs are often reduced because SOILMatrix can also serve as the drainage portion of the greenroof system. When used for storm water management, the porous planting medium allows rain water to readily penetrate the soil surface. This reduces runoff and allows pollutants to be naturally filtered and remediated thereby improving water quality.

Connecticut Convention Center, Hartford, CT. 9th floor walkway from the convention center to the parking garage.

SOILMatrix particle showing interior voids

What is SOILMatrix?

SoilMatrix is a lightweight, ceramic material produced by expanding and vitrifying select shales, clays and slates in a rotary kiln. The process produces a high quality ceramic aggregate that is structurally strong, physically stable, durable, environmentally inert, light in weight, and highly insulative. It is a non-toxic, absorptive aggregate that is dimensionally stable and will not degrade over time.

SOILMatrix: A comparison to other aggregates

Natural sand and soil are heavy. They frequently require that structural modifications be made to the project's design. Native soils have silts and clays that may clog the filter materials or drainage layers and reduce effectiveness. The physical properties of natural volcanic aggregates vary widely with source and location. Natural materials may degrade and compact over time, and require additions to or replacement of planting media. Some horticultural products used in greenhouses and container planting, such as vermiculite and perlite, are extremely light in weight and do not offer adequate anchorage and support for larger plants. In exterior applications vermiculite and perlite often float to the top of the planting media where they can be carried away by wind or water.

Tubes containing equal weights of soil, gravel, SOILMatrix, limestone and sand to demonstrate the difference in relative volume.

LEED™ Benefits

The Leadership in Energy and Environmental Design (LEED) system was designed by the United States Green Building Council (USGBC) to evaluate the influence of building design and construction on the environment. SoilMatrix is an environmentally friendly, lightweight, ceramic product that saves material, labor and transportation cost. It also improves the functionability and service life when used in greenroofs and other planting media. These benefits support sustainable development and contribute to designs becoming LEED certified. For more detailed information on LEED, see ESCSI Publication # 7700.

LEED-NC Rating System Summary (Version 2.1)

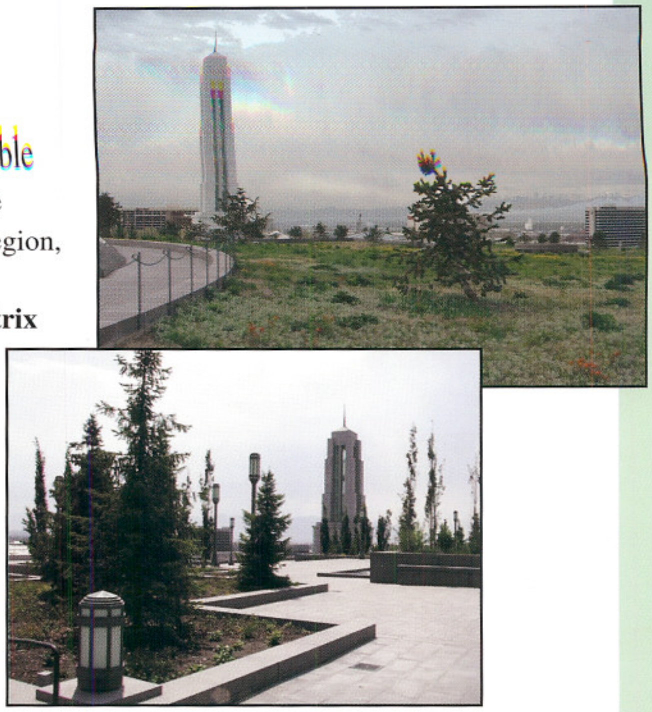
Category	Available Points	Points Where SOILMatrix Can Contribute
Sustainable Sites (Section 6.1, 6.2,7.1,7.2)	14	4
Water Efficiency (Section 1.1, 1.2, 2)	5	3
Energy & Atmosphere	17	*(see note 1)*
Materials & Resources (Section 5.1, 5.2)	13	2
Indoor Environmental Quality	15	*(see note 2)*
Innovation & Design	5	*(see note 2)*
Total Possible Points	**69**	**9+**

Note (1): *1-10 points can be awarded for energy cost savings of 15%-60% for new buildings and 5%-50% for existing buildings. Improving the thermal performance of building materials contributes toward obtaining these credits.* **Note (2)**: *Ideal for indoor planting media.*

SOILMatrix: The Versatile Planting Medium

Designers can count on SOILMatrix to be predictable, stable and highly dependable for the duration of the greenroof. The planting media mixture will vary depending on the climate region, application, aggregate and types of plantings specified. **For optimal results it is essential to consult with the SOILMatrix supplier during the design phase of the project.**

Sedums flourishing in extensive SOILMatrix blend



2 views of greenroof at LDS Conference Center, Salt Lake City, UT

SOILMatrix is readily available throughout the United States and Canada, and is sold under various trade names.

For additional information and technical support contact the local supplier or

ESCSI

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Publication # 8621

4/2005-5M

13C

ESCSI Project of the Month August 2002
"Utelite's Environmentally Engineered Soil (E-Soil)Meets Horticultural Challenges in 5-Acre Rooftop Garden"

ESCSI

FEATURED PROJECT 08-2002 UTELITE

LDS Conference Center (Part 2- Horticultural)

LOCATION
Salt Lake City, Utah

ARCHITECT
Zimmer Gunsul Frasca
Portland, OR

LANDSCAPE ARCHITECT
Olin Partnership of Philadelphia

OWNER
(LDS) The Church of Jesus Christ of Latter-Day Saints

GENERAL LANDSCAPE CONTRACTOR
American Landscape, Inc.

LIGHTWEIGHT AGGREGATE PRODUCER
Utelite Corporation

TOTAL CUBIC YARDS OF UTELITE'S ENVIRONMENTALLY ENGINEERED SOIL (E-SOIL)
20,000 Cu. Yds.

PROJECT SPECIFICATIONS
Facility: 1,500,000 sq. ft. highlighted by a 21,000-seat, 600,000 sq. ft. assembly hall, and including a 900-seat theater, and 1,300-car underground parking structure, and a a richly landscaped 5-acre rooftop garden

Utelite's Environmentally Engineered Soil (E-Soil) Meets Horticultural Challenges In 5-Acre Rooftop Garden

(See Part 1 for Structural Lightweight Concrete Information)

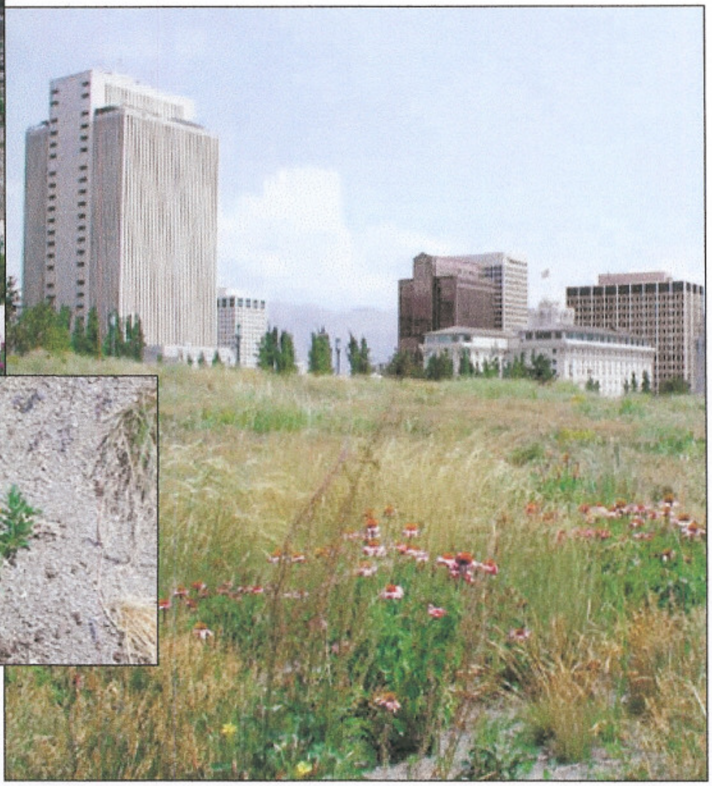
The Church of Jesus Christ of Latter-Day Saints (LDS) Conference Center Complex in Salt Lake City, Utah

UNIQUE BUILDING MARKS 150th ANNIVERSARY

The July 24, 1997 groundbreaking marked the 150th anniversary of the arrival of the first Mormon pioneers to the Salt Lake Valley, a truly significant date in Utah's history, and heralded the beginning of a remarkable and demanding experience for the Church of Jesus Christ of Latter-Day Saints. The new 1,500,000 square foot Conference Center is a unique building in countless ways – both in its design and construction. The LDS Church wanted a facility that would last 150 years! That meant designing a structure that would not only meet but vastly exceed the 1994 Uniform Building Code in which Salt Lake City is designated in a seismic Zone 3.

Utah "prairie" planted in Utelite E-Soil is a unique feature of Center's rooftop garden

LDS Conference Center (Part 2 - Horticulture)



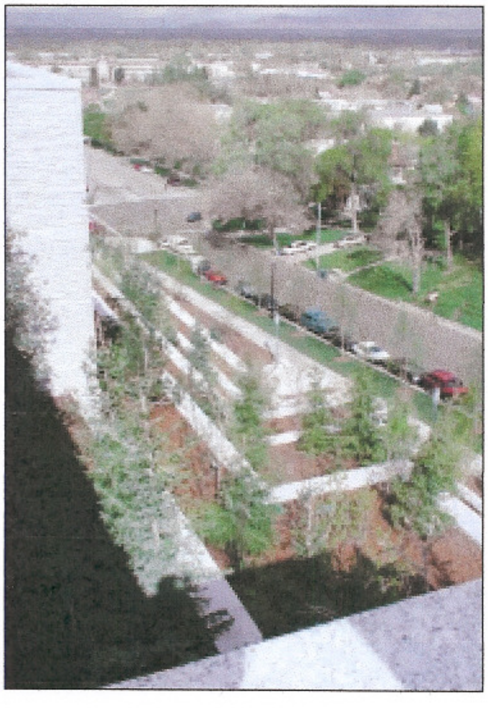
Utelite E-Soil provides the advantages of a lightweight fill and excellent growing medium in one product.

UTELITE SHARES IN THE 150TH ANNIVERSARY CELEBRATION BY HIGHLIGHTING THE ROOFTOP LANDSCAPING

The Conference Center has won numerous national and international architectural and structural design awards.

The concepts and design of the Conference Center land-scaping is certainly a site to behold. It was designed by Olin Partnership of Philadelphia and executed by American Landscape, Inc., of North Salt Lake. The rooftop garden is self-maintaining with minimal maintenance while using fifty percent less water than normal landscapes use. American Landscape installed over 20,000 cu. yds. of Utelite E-Soil, a sub-drainage system, roof and plaza deck drains, a free anchor system,

The trees, flowers, shrubs and grasses of the "self-maintaining" rooftop garden reflect the natural beauty of Utah and features 7 different microenvironments



an irrigation system, and all plants and foliage which included over 1,300 trees, 1,450 shrubs, and 27,000 bulbs. The overall landscaping of the building is impressive to say the least.

The plants used for the Conference Center are very different from those used around Temple Square. There are no annual plants – only woody and herbaceous perennials, with various trees and shrubs. The rooftop garden is essentially a Utah mountain. The North slopes contain messic or moisture loving plants, whereas the South facing slopes have the xeric or more drought tolerant plants such as juniper and sagebrush. A portion of the flattop roof garden represents a high mountain meadow. Two longtime forest ecologists were brought in and helped formulate the planting that would be used for the meadow. In all, seven different microenvironments were identified; over twenty-one varieties of wild grasses were used; and, three hundred varieties of wild flowers were employed.

According to Peter Lassiq, Head Gardener for the

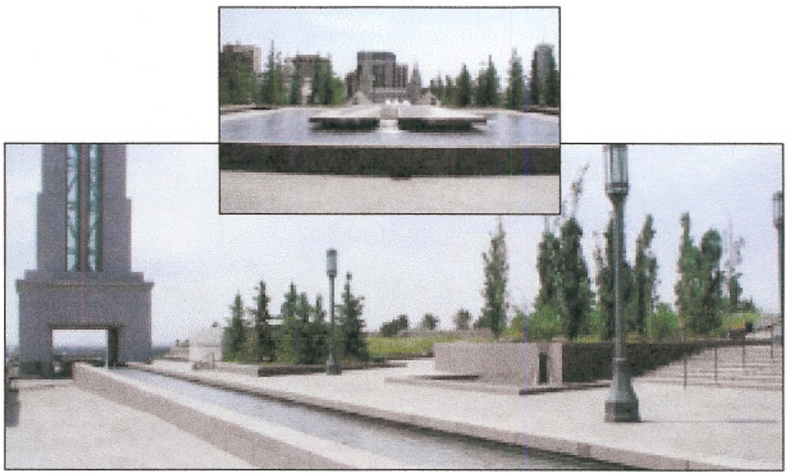
LDS Church, "After all is said and done, topsoil is not available on today's market. The topsoil that is available now isn't a very dependable variety. It might be sandy, silty, or it may be clay. Topsoil really isn't dependable anymore; so, we went with Utelite E-Soil. Utelite E-Soil works the same as regular soil, but better, because it doesn't have weeds. It doesn't have morning glory, diseases or insects in it. It really comes out clean."

The Utelite E-Soil mixture for the LDS church is approximately 50% Utelite and 50% peat moss.

Garden design uses Utah's native flora planted in Utelite's E-Soil mixture

LIGHTWEIGHT CONCRETE DETAILS

Structural lightweight concrete was used extensively to lighten the dead load and help solve the design and seismic demands placed on the structure. In the roof system 15,000 cubic yards of 4,000 and 6,000 psi lightweight concrete weighing 110 lb/ft^3 were used. In the wall systems, 120,000 lightweight concrete masonry units, with a maximum weight of 28 lbs. per 8 x 8 x 16-inch unit, were used. The CMU's were manufactured by Amcor Masonry Products and installed by B&T Masonry.



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