

Structural Lightweight Aggregate and Concrete

How a 90-Year-Old Industry Finds Itself on the Leading Edge of the Sustainability Movement

By John Ries, P.E.

Structural lightweight aggregate has been successfully used for well over two millennia. It has had widespread use for the past ninety years. This track record of proven performance has demonstrated how structural lightweight aggregate contributes to the sustainable development by conserving energy, lowering transportation requirements, maximizing design and construction efficiency and increasing the service life of the product it is used in.

There are three common types of lightweight material: aggregate from volcanic sources, byproducts from coal combustion, and manufactured aggregates. This article covers expanded shale, clay and slate (ESCS), the manufactured lightweight aggregate that is predominately used in the markets discussed. ESCS 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. (Figure 1)

ESCS has been used with great success around the world in more than 50 different types of applications. The most common among these are concrete masonry, high-rise buildings, concrete bridge decks, precast and prestressed concrete elements, asphalt road surfaces, geotechnical fills and soil conditioner for horticultural applications.

Improved Concrete Durability

As we all know, concrete failing prematurely should not be tolerated. A major source of failures is initiated at the cracks, whether they are micro-cracks or macro-cracks. Therefore, mitigating cracking becomes an essential element in concrete durability. Adding lightweight aggregate to the concrete mitigates crack formation by creating a high quality contact zone at the lightweight aggregate/cement matrix interface. This zone has very low levels of micro-cracking throughout the mortar matrix. Lightweight concrete's high resistance to weathering and corrosion is developed by the significantly higher aggregate/matrix adhesion

and by the reduction of internal stresses due to elastic matching of lightweight aggregate and matrix phases.

When ESCS is used, concrete permeability is reduced regardless of concrete strength, as compared to its normalweight aggregate counterpart.

Even though it has been known for over 50 years that the use of lightweight aggregate produces a more forgiving concrete that is less sensitive to poor field-curing conditions, it is just recently being used for that specific purpose. With lightweight concrete, the cementitious hydration is enhanced due to the process of internal curing. This improved hydration is provided by the moisture available from the slowly released reservoir of water absorbed within the pores of the aggregate. Time-dependent improvement in the quality of concrete containing lightweight aggregate is greater than that with normalweight aggregate

Design and Construction Efficiency

A major reason lightweight concrete is used is for weight reduction, which often enhances the functionality, architectural expression, and constructability of a structure (Figure 2). In buildings, this is achieved by thinner fire resistant slabs, longer spans, expressive roof designs, taller buildings, additional floors



Figure 1: ESCS aggregate is user friendly.



Figure 2: ESCS is half the weight of ordinary aggregates.

added to existing structures, and lower column and bearing wall loads when buildings are located on poor soil conditions.

Reduced weight often reduces the overall amount of building materials needed for projects. This often occurs with smaller footings, fewer piles, smaller pile caps, less reinforcing, and smaller supporting members (decks, beams, girders, and piers). Reduced weight also results in reduced inertial seismic forces.

With bridges, this may allow a wider bridge deck (additional lanes) being placed on existing structural supports with minor or no modifications. Reduced weight also allows for longer spans, fewer piers; or, in the case of balanced cantilever bridge construction, equal weights can be maintained where one side needs to be longer than the other.

The use of lightweight aggregate allows for the manufacturing of longer or larger precast members 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.

The use of lightweight aggregate allows enhanced design flexibility and project economics by being able to specify densities ranging from less than 110 pounds per cubic foot to 140 pounds per cubic foot. This ability to specify concrete densities is driven by the engineer's decision to improve structural efficiency (strength to density ratio), to reduce concrete product transportation and construction cost, and to enhance the hydration of high cementitious concrete with very low water/cement ratios.

Construction requires transportation! Therefore, there is a direct correlation between cost and environmental impact. Transportation costs are directly related to the weight of concrete products, demonstrating a significant



Figure 3: ESCS allows for transportation of longer precast members.

economic advantage when using lightweight concrete. Fewer trucks in congested cities are not only an environmental necessity, but will also generate fewer public complaints. (Figure 3)

The best example of lightweight concrete and ergonomics is with concrete masonry. By reducing the weight that must be physically handled by labor, we enhance sustainability of our workforce. At the same strength, lightweight concrete units are up to 40% lighter than traditional units. This reduces the physical demands on labor and equipment and, at the same time, increases productivity while lowering injuries and workers' compensation claims. Again, as with structural lightweight concrete building elements, the reduced weight of lightweight concrete masonry units also results in reduced inertial seismic forces.

Horticulture and Environmental Applications

The use of lightweight aggregate in site development (Figure 4) assists designers in addressing the important issue of storm water management with on-site treatment. ESCS can help to reduce the heat island effect by amending soil to improve landscaping and making the use of "green roofs" not only desirable, but also economically feasible. ESCS is environmentally friendly. It is non-toxic, odorless, 100% inert, and will not compress, degrade, decompose, or react with agricultural or horticultural chemicals. It acts as an insulator in the soil mixture and protects plants from rapid temperature extremes. ESCS retains a high percentage of its weight in absorbed water and waterborne nutrients, making it an excellent buffer. It is



Figure 4: ESCS used on the right allows for better vegetation growth.

user friendly because it is lightweight, inert, pH adjustable, easy to handle, and economical to use.

Realizing that true sustainability of a product, building or civilization must begin in the design phase with a shift of beliefs and attitudes, the use of lightweight aggregate is a small but important step toward enhancing the performance of the products in which it is used, thereby helping to provide an environment that is sustainable and more people friendly. ■

John Ries, P.E. is president of the ESCSI, has been in the design and construction industries for over 40 years, and specifically involved with the Lightweight Aggregate Industry the last 22 years. He is a professional engineer and is active in ACI, ASTM and several other national organizations that serve the aggregate and concrete industries.

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