Expanded Shale Clay and Slate in Water Filtration

ESCSI

Expanded Shale, Clay and Slate Institute

Rotary Kiln Structural Lightweight Aggregate

Expanded Shale, Clay and Slate (ESCS) filtration media has up to 100 times the specific surface area than ordinary filtration sand and gravel. This advantage combined with ESCS's lower density and excellent durability offer superior performance, increased volume flows and reductions in clogging or blinding over standard silica, granite or quartz granular media. ESCS is manufactured and available throughout the United States and is a reliable, economical solution for water filtration in applications where sands and gravels are used. ESCS is often the best choice in a variety of filter media applications, from storm water runoff to industrial wastewater filtration.

ESCS Filtration Media

Properties and Applications

For 100 years, select shales, clays, and slates have been expanded in rotary kilns to produce structural ESCS aggregate for use in various lightweight design applications ranging from geotechnical fill, structural concrete, and masonry. Several million tons of ESCS are produced annually. Its availability is widespread throughout most of the industrially developed world and is now commonly used as a granular filtration media replacing traditional sands and gravels in filtration applications worldwide. ESCS's excellent performance as a filtration media stems from its unique physical properties that are created during the vitrification process, all of which assure a strong stable media. They are:

- Increased surface area
- Deeper bed aeration
- Increased permeability
- Reduced weight
- Lower particle specific gravity
- Improved engineered gradings
- Higher angle of internal friction
- Inert, Non-toxic
- Non-degradable

PHYSICAL PROPERTIES OF ESCS AGGREGATES

Particle Specific Surface Area

The surface area of filtration media has a significant influence on performance. The term *specific surface area* refers to the surface area per unit mass of a filtration media and is usually expressed as m^2/g. The specific surface area is closely related to, and often the dominant factor in, a media's performance in the physical adsorption of suspended particles and chemical compounds as well as providing habitat for beneficial micro-organisms.

The specific surface area of ESCS fine media (< 4.75 mm) can be up to 50 m^2/g which is much greater than typical silicious media. Coarse ESCS media (> 4.75 mm) can approach 15 m^2/g. For comparison, the specific surface area of some clay minerals can range from 10 to 70 m^2/g (Carter et al., 1986); whereas, ordinary sands can be as low as 0.0011 m^2/g (Jackson, 1979). This increase in surface area is the key for a media with a larger effective size and a higher than usual uniformity coefficient (UC) to achieve the desired filtration results with improved water flow and less clogging.

Particle Shape and Particle Distribution

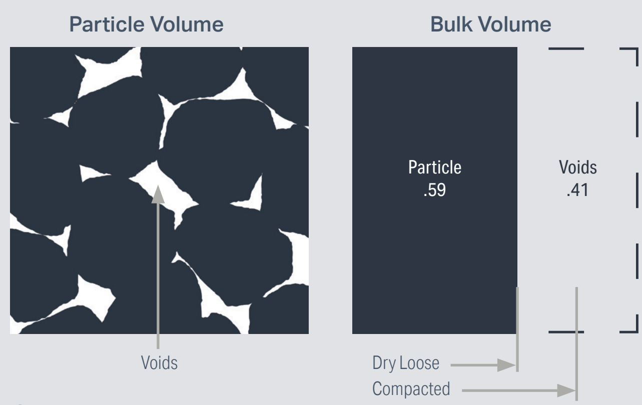
As with naturally occurring granular materials, ESCS materials have particle shapes that vary from round to angular. ESCS particle size distribution conforms to the requirements of ASTM C-330. The narrow range of particle sizes ensures a high interstitial void content that approaches 50% in the loose state. North American rotary kiln plants producing ESCS currently supply coarse and fine aggregates with 20 mm to 5 mm (3/4″ - #4), 13 mm to 5 mm (1/2″ - #4), or 10 mm to 2 mm (3/8″ - #8) gradations, as well as various fine aggregate gradings. Coarse gradations have a minimum percentage of fines smaller than 2 mm (#10 mesh) and insignificant amounts passing 150 µm (#100 mesh screen). Custom sizes may also be available. Traditional media for sand filtration systems is coarse sand with an effective size (D10) between 0.3mm and 0.5mm with a uniformity coefficient (UC) of less than 4.0. The open grading and wide particle distribution found in ESCS media allows for deeper bed depth penetration of suspended solids, reduced blinding or clogging, and reduced frequency of back flushing in filtration systems. The lower specific gravity and increased surface area of the particles facilitate faster expansion of the filter bed in back flushable systems. These attributes offer a quicker cleansing of the bed, using less water during the back flush.

Filtration Trench

Particle Porosity and Bulk Density

When suitable shale, clay, and slate are heated in a rotary kiln to temperatures in excess of 1100° C (2000°F), a cellular structure is formed of spherical pores surrounded by a strong, durable ceramic matrix that has characteristics similar to those of vitrified clay brick. Oven-dry specific gravities of ESCS vary but commonly range from 1.25 to 1.85. Combination of this low specific gravity with high interparticle void content results in bulk dry densities commonly in the range of 480 to 965 kg/m³(30 to 60 lbs/ft³).

Differences in porosity and bulk density between ESCS media and normal weight media is illustrated. For comparative purposes, *Figure 1* shows the interparticle voids in coarse media. Although normal weight media commonly have absorptions of 1% - 2%, the schematic assumes ordinary aggregates to be 100% solid. For illustrative purposes, the bulk volume is shown to be broken into one entirely solid part with the remaining fraction being interparticle voids.



Gravel

Loose 1520 kg/m³ (95pcf)
Compacted 1680 kg/m³ (105pcf)

Particle Volume (Loose)

$$\frac{1520\ \text{kg/m}^3}{2600\ \text{kg/m}^3} = .59$$

Particle Volume (Compacted)

$$\frac{1680\ \text{kg/m}^3}{2600\ \text{kg/m}^3} = .65$$

[2600 kg/m³ is the particle density of ordinary aggregate.
SG = 2.60 x 1000 kg/m³]

Figure 1 **Voids in Ordinary Coarse Media**

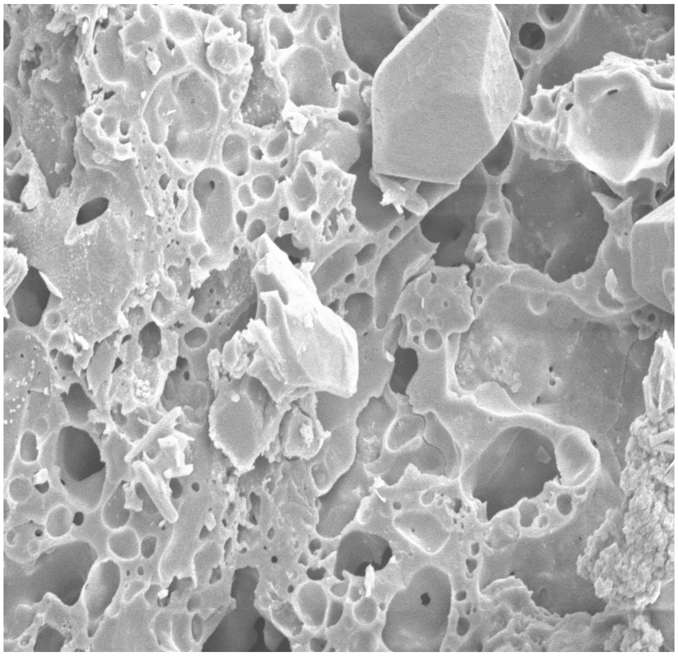
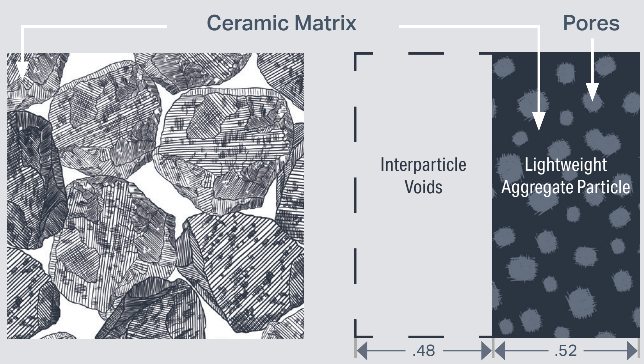


Figure 2 **Cellular Pore Structure ESCS Media**

Figure 2 shows the cellular pore structure of an ESCS media. When the moisture content is known, the oven-dry specific gravity may be directly computed. This representative ESCS media with a measured dry loose bulk unit weight of 714 kg/m³ (44.6 lbs/ft³) and computed oven-dry specific gravity of 1.38 results in the aggregate particle occupying 52% of the total bulk volume, with the remaining 48% composed of interparticle voids.

The specific gravity of the pore-free ceramic solid fraction of ESCS lightweight aggregate may be determined by standard procedures after porous particles have been thoroughly pulverized in a jaw mill. Pore-free ceramic solids specific gravities measured on several pulverized ESCS samples developed a mean of 2.55. The representative ESCS with a dry specific gravity of 1.38 will develop a 54% fraction of enclosed aggregate particle ceramic solids and a remaining 46% pore volume (***Figure 3***).

This leads to the illustration of the total porosity in a bulk loose ESCS sample as shown in ***Figure 4***. Interparticle voids of the overall bulk sample are shown in the enclosed dashed area, and the solid pore-free ceramic and the internal pores are shown within the solid particle lines. For this representative ESCS, the dry loose bulk volume is shown to be composed of 48% voids, 28% solids, and 24% pores.



$$SpG_{Dry}\text{ (Dry Specific Gravity)} = \frac{\gamma M\text{ (Partially Saturated Surface Dry Specific Gravity)}}{(1\text{-}M)\text{ (1-Day Soak Moisture Content by Weight)}}$$

$$SpG_{Dry} = \frac{1.50}{(1+.085)} = 1.38$$

Measured bulk. Dry loose density.

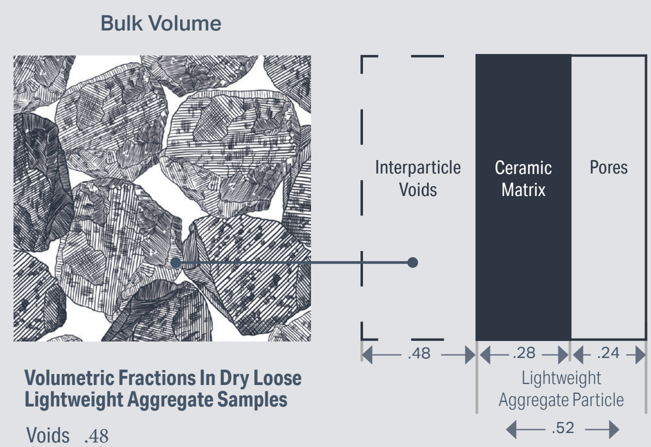
$$\text{Fraction of light bulk aggregate sample occupied by lightweight aggregate particles} = \frac{714\ kg/m^3}{1380\ kg/m^3} = .52$$

$$\text{Fraction of bulk aggregate sample occupied by interparticle voids} = 1.00 - .52 = .48$$

$$V_s\left(\text{Fractional Part of Lightweight Aggregate Particle Occupied by Ceramic Matrix}\right) = \frac{SpG_{Dry}}{SpG_{Dry}\text{ of Pore-Free Ceramic Mix}}$$

$$V_s = \frac{1380\ kg/m^3}{2550\ kg/m^3} = .54\text{, then } V_{pores} = 1 - .54 = .46$$

Figure 3 **Interparticle Voids and Within-particle Pores of ESCS**



Volumetric Fractions In Dry Loose Lightweight Aggregate Samples

Voids .48
Ceramic Solids Fraction = .52 x .54 = .28
Lightweight Aggregate Pores = .52 x .46 = .24

Loose Aggregate Condition	Interparticle Voids	Ceramic Matrix	Pores	Density kg/m³
Dry	–	714	–	714 (44.6 pcf)
Partially Saturated 1-Day Dry Soak	–	714	61	775 (48.4pcf)
Vaccuum Saturation	–	714	240	954 (59.6 pcf)
Long Time Saturation (Submerged)	480	714	240	1434 -1000 = *434 (27.1pcf)

*Buoyant Unit Weight

Figure 4 **Voids, Pores, and ceramic matrix fraction in an ESCS sample**

Waste Water Filtration

Storm Water Bed Filtration

Trickle Bed Filter

Absorption Characteristics

ESCS materials that are continuously submerged will, continue to absorb water over time. This will increase the materials specific gravity, reducing the amount, if any, of floating particles. This may take up to 72 hours.

Durability Characteristics

The durability of ESCS used in structural applications is well known. Long-term durability characteristics of ESCS were demonstrated in 1991 by reclaiming and testing samples of the ESCS fill supplied in 1968 to a Hudson River site. Magnesium soundness tests conducted on the reclaimed aggregate sample exposed to long-term weathering resulted in soundness loss values comparable to those measured and reported in routine quality control testing procedures 23 years earlier, indicating little long-term deterioration due to continuous submersion and freeze-thaw cycling at the waterline.

Although hardness limits of granular filtration materials is a requirement of AWWA standards using the Moh's scale, it is well known and discussed in ANSI/AWWA B100-01 Section II.E "Anthracite Quality Tests", that Moh's testing does not accurately define the hardness of coal. This is also true with ESCS materials due to its surface texture and porous structure. It is recommended by the Expanded Shale, Clay and Slate Institute as a best practices approach, to test the durability of granular filtration materials by the Durability Indexing method (ASTM D-3744). This will give the user of any type of granular filtration material a direct comparison of media durability to media known to have expectable levels of performance.

Permeability

Attempts to measure permeability characteristics of unbound ESCS have not been informative because of the inability to measure the essentially unrestricted high flow rate of water moving through open-graded structure. This characteristic has also been observed in the field, where large volumes of water have been shown to flow through ESCS drainage systems. Exfiltration applications of ESCS have demonstrated a proven capacity to effectively handle high volumes of storm water runoff. Subterranean exfiltration systems have provided competitive alternatives to infiltration ponds by not requiring the usage of valuable space as well as eliminating the long-term maintenance associated with open water storage systems.

ESCS APPLICATIONS

Wastewater

- Sand filter (intermediate, mound, trickling-recirculating, septic systems, etc.)
- Constructed Wetlands for re-use/release
- Industrial Fluid

Stormwater

- Sand filter (Austin Surface Sand Filter, Delaware Sand Filter, DC Underground Fault Sand Filter, etc.)
- Bioretention, Bioswales and Filter Strips
- Polishing filter for high flow stormwater devices
- Permeable pavement base filtration
- Enhanced water storage space
- Infiltration Trenches

ECONOMICS

Treatment Efficiencies

- Longer life cycles – Filter run times improved up to 50% without loss of performance
- Filter bed expansions can be achieved with 15% less backflush water
- Good ESCS pore space allows use of coarser media to maintain bioactive sites
- Little to no crusting and ponding

Lower Operating and Maintenance costs

- Twice as much volume of ESCS can be transported per load as compared to normal weight, cutting the number of trucks by half.
- Loader or crane volume can be increased to allow faster placement and longer reaches.
- In tight spaces where hand placement and compaction is required, ESCS is much easier to handle, offering considerable labor savings.

General Properties of ESCS Aggregate used in Filtration Applications

Aggregate Properties	Test Method	Typical Values for ESCS	Typical Values for Granular Filter Materials
Surface Area	EGME Sorption Method	5 m^2/g – 19 m^2/g	0.001 m^2/g – 3 m^2/g
Specific Gravity	ASTM C127/128	1.25 – 1.85	2.65 – 2.75
Durability Index	ASTM D3744	82 – 93	80 – 99
Magnesium Soundness	ASTM C88	< 6%	< 6%
Acid Solubility	ASTM D3042	1% – 4%	0.3% – 93%
Caustic Solubility	ASTM D1109	0% – 0.9%	0% – 1%
pH	pH Meter	6 – 10	6.5 – 11
Organic Impurities	ASTM C40	< 0.5%	0.5% – 10%
Permeability (Constant Head)	ASTM D2434	50in/hr – 1300 in/hr	1in/hr – 600 in/hr
Loose Dry Density	ASTM C29	30 lb/ft^3 – 60 lb/ft^3	90 lb/ft^3 – 105 lb/ft^3
Loose Wet Density	ASTM C29	45 lb/ft^3 – 70 lb/ft^3	95 lb/ft^3 – 110 lb/ft^3
Los Angeles Abrasion	ASTM C131	20% – 40%	10% – 45%

Industrial Sludge Bed Media

Expanded Shale, Clay and Slate Institute

35 E. Wacker Drive, Suite 850
Chicago, IL 60601

Ph: 801-272-7070
Fax: 312-644-8557 • info@escsi.org

www.escsi.org

Expanded Shale, Clay and Slate Institute
Rotary Kiln Structural Lightweight Aggregate

Publication #8676 · 02-2018