Expanded Shale, Clay and Slate Institute

Rotary Kiln Structural Lightweight Aggregate

Solving Geotechnical Challenges with

Structural Lightweight Aggregate Fill

As less buildable land is available, the need for creative solutions for today's unique geotechnical challenges becomes obvious. Soft and unstable soils along with tight construction schedules are common in several areas of the country. The use of compacted fills utilizing Expanded Shale, Clay and Slate (ESCS) lightweight aggregates is a proven solution for these problems.

ESCS fills are approximately half the weight of fills using common materials. The load reduction, coupled with the high internal friction angle of the lightweight aggregate can reduce vertical and lateral forces by more than one-half. ESCS has been used to solve numerous geotechnical engineering problems and to convert soft and unstable soil into usable property.

ESCS fills require no special construction equipment or forms to install. They can be placed in all types of weather using common site equipment . ESCS fills have a proven record of ease of use and durability under extreme conditions. They do not require liners and do not require additional steps to prevent buoyancy issues. ESCS fills utilize a lightweight angular manufactured aggregate that is structurally strong and free draining. Since water moves easily through the product, no special drainage channels need to be placed throughout the fill.

Method of Construction

ESCS fills are placed in approximately uniform layers not to exceed 12 inches loose thickness. Each layer shall be compacted using vibratory compaction equipment weighing not more than 12 tons static weight. The actual lift thickness, exact number of passes, and need for vibrating the roller will be determined by the engineer, depending on the project requirements (i.e., strength, compressibility, density) and equipment used. The contractor shall take all necessary precautions during construction to ensure that the material is not over-compacted. This includes activities in operations on or adjacent to the lightweight fill. Construction equipment, other than for compaction, should not operate on the exposed lightweight fill.

The following examples show solutions to common geotechnical problems

Insulating Backfill

***Solana Solar Power Plant**, Gila Bend, Arizona*

90,000 cubic yards

The $2 billion Solana Generating Station was built 70 miles southwest of Phoenix, AZ in the desert along Interstate 8 as a source of renewable energy.

When commissioned, it was the largest parabolic trough plant in the world and the first U.S. solar plant with molten salt thermal energy storage, so electricity can be supplied at night or on cloudy days. The molten salts are heated by the plant's 3,232 solar collector assemblies and stored in twelve, 140-foot-diameter tanks. The massive tanks extend approximately 45 feet into the air and the foundations extend 18 feet below ground, where the tanks were surrounded by ESCS lightweight aggregates specified for their insulating properties. The ESCS fill used on this project had a thermal conductivity of approximately 0.08 BTU/hr ft ºF.

This plant has a total capacity of 280 megawatts (MW) gross, from two 140 MW gross (125 MW net) steam turbine generators, which is enough to power 70,000 homes while avoiding around 475,000 tons of CO^2 every year.

The Arizona Public Service (APS) has contracted to purchase 100% of the power output generated from Solana, to meet the Arizona Corporation Commission's (ACC) mandate that the state's regulated utilities provide 15% of their electricity from renewable energy sources by 2025.

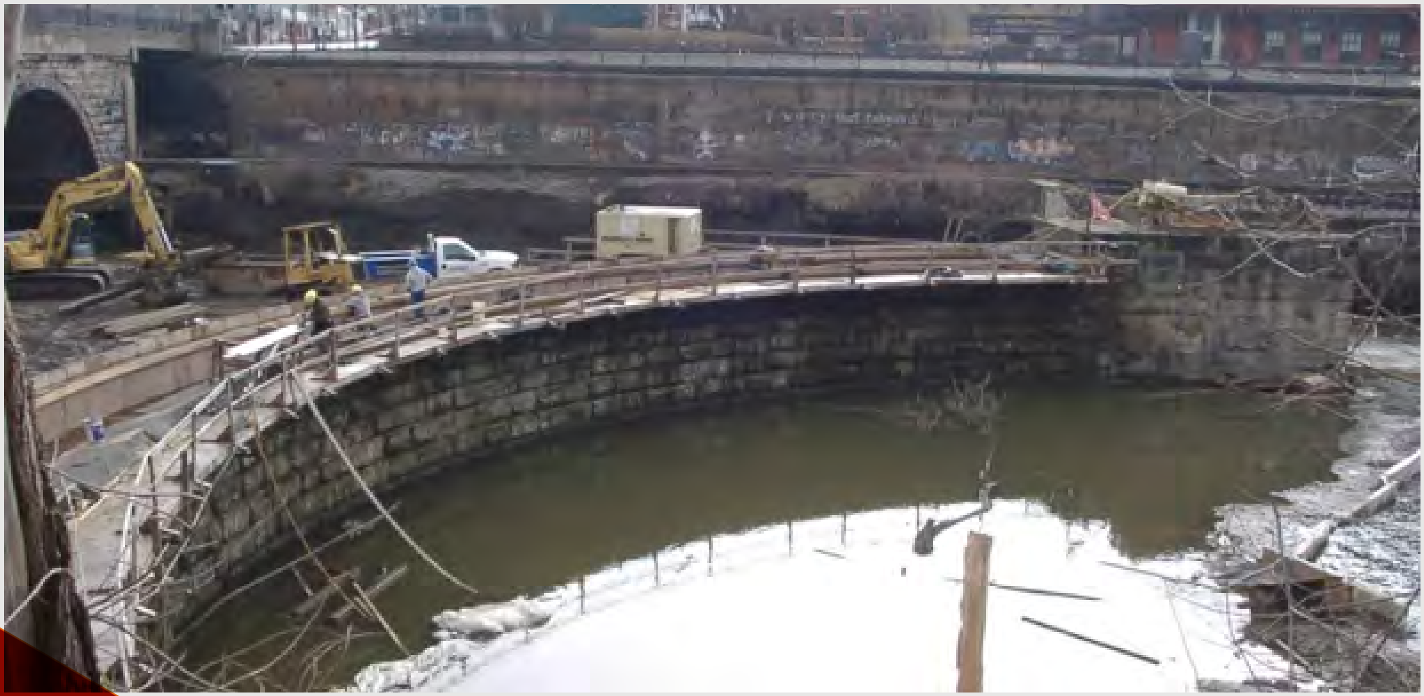
Backfill Behind Segmental Retaining Walls

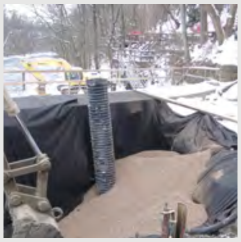
***Bluff Restoration**, Natchez, Mississippi*

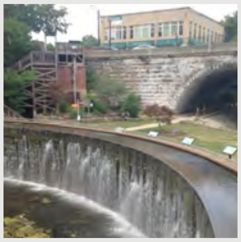
15,600 cubic yards

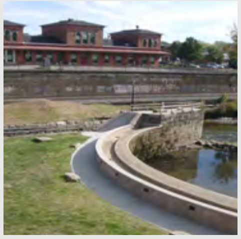
The slopes of the bluffs along the Mississippi River, upon which the City of Natchez resides, were failing, endangering the very existence of portions of this historic city. The slopes were stabilized using a system known as soil nailing. After stabilizing the slopes, the slope surfaces were covered with shotcrete. A facing of segmental concrete masonry wall units (SRWs) was placed in front of the shotcrete slopes to provide a more attractive appearance.

The space between the shotcrete surface and the SRW walls was filled with ESCS lightweight aggregate. The specifications required maximum in-place compacted densities of 65 pounds per cubic foot. The angle of internal friction was specified at a minimum of 40 degrees when measured in direct shear.









Backfill behind Historic Structure

***Kent Dam**, Kent, Ohio*

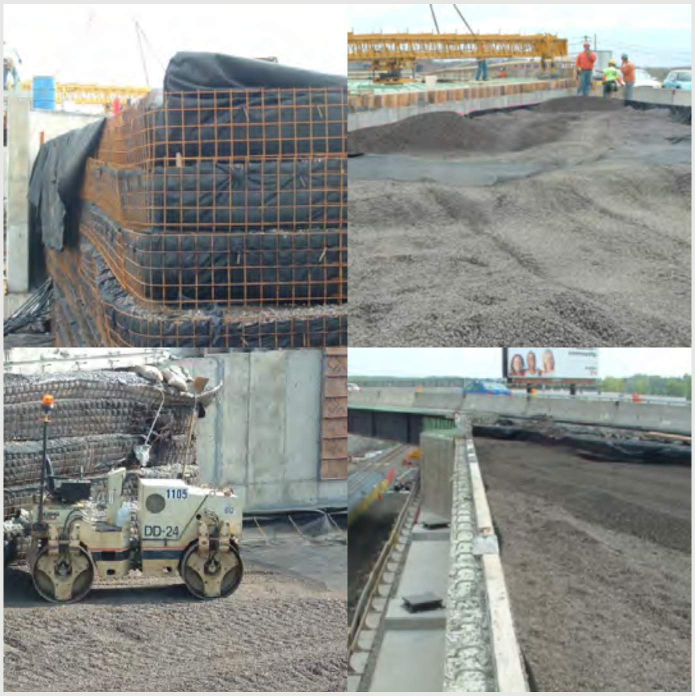
2,500 cubic yards

The Kent Dam project was first introduced to City officials in 1998 by the Ohio EPA. The modification–removal of the Kent Dam was recommended to improve water quality in the Middle Cuyahoga River. This request for modification-removal of the dam was a highly emotional issue for the citizens of Kent, considering the unique features of the dam.

The dam was constructed in 1836 and had been an historic icon in downtown Kent for 165 years. The dam was a "highly engineered structure" for its time that consisted of hand-cut sandstone blocks that are stacked 14 feet high and 125 feet long in the shape of an arch. The associated waterfall has been the backdrop of family photos and community events for several generations of Kent residents.

A plan was devised to keep the original dam and allow the river to bypass the dam on the east side of the structure. The "new" land (drained dam pool area) that was created directly behind the Kent Dam was transformed into "Heritage Park." This area is a combination of heavy stone slabs to armor against the river's erosive power, a grassy lawn area, a flower garden and several sandstone blocks salvaged from the canal lock area used for landscaping purposes. Three new observation platforms were also included within the project area: one at the newly created Main Street Bridge park entrance; one on top of the new pumphouse; and one on top of the newly reinforced east dam abutment.

Public hearings identified the water cascading over the dam a "must have" historical feature. The only available remedy to accommodate this was to create a re-circulating waterfall that pumped water from the river into a weir located around the lip of the dam. This feature was included in the final design. To accommodate the new design elements and the existing historic structure the area immediately behind the structure was removed and ESCS lightweight aggregate was used. The properties of the ESCS fill reduced the load against the dam while supporting the new weir at the dam face.



Fill Behind Bridge Abutments

I-90, Everett Road Exit 5A (Bridge over CSX Spur), Albany, New York
8,500 cubic yards

The New York State Department of Transportation rehabilitated an existing bridge that carried traffic on I-90 over an active CSX Railroad Spur in Albany, NY. The construction was performed in phases as not to interrupt traffic flow.

New skewed abutments were cast in place in front of the existing abutments shortening the span of the replacement bridge. One of the challenges the designers faced was to limit the load on the existing soils behind the new abutments. Lightweight aggregate was the solution.

ESCS lightweight aggregate backfill reduced the load on poor subsoils, thus minimizing settlement and the possibility of the dip in the road commonly found at the end of a bridge. Because of the high angle of internal friction, the lateral pressures acting on the abutments were significantly reduced when compared to conventional sand, stone or clay backfill.

The lightweight aggregate was placed in 12-inch lifts on top of geotech fabric and then compacted to the bottom of the pavement course. The use of a welded wire mesh and geotech fabric held the lifts of lightweight aggregate in place while constructing the new travel lanes. This allowed the highway to remain fully open while the phased construction took place. Additional lightweight aggregate was placed against the baskets to create the finished slopes.

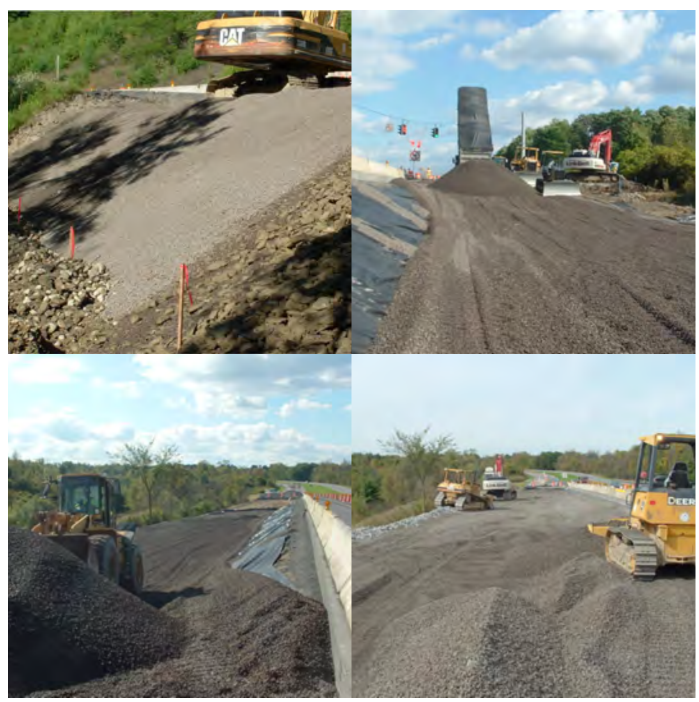
Slope Stability

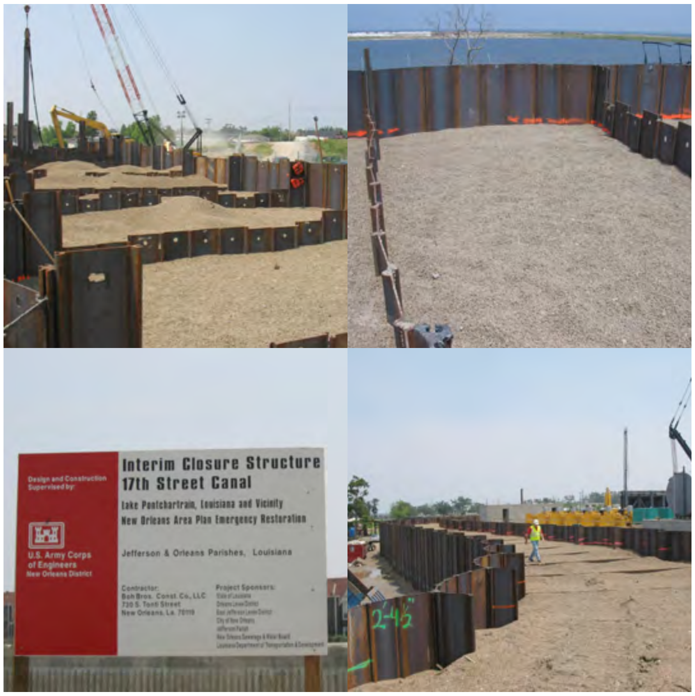
New York Route 32 at Kenwood Road, Delmar, New York
5,200 cubic yards

In 1963, the New York State Department of Transportation constructed a bypass around Delmar, NY to alleviate the congestion in this suburb of Albany. The divided highway utilized cut and fill techniques to build the highway around hills and valleys. After decades of use, the intersection at Kenwood Road began to show signs of problems with the original construction. The fill used to build up the grade for the roadway, started to slip causing movement in the highway. The embankment began to fail due to subsurface sliding because of soft soil seams close to grade level.

To improve the stability of the hillside and avoid movement of the roadway, ESCS lightweight fill was specified. The reduction of the gravitational force driving the slope failure combined with the high angle of internal friction of the lightweight aggregate fill provided the solution for this problem.

The outside lane and the hillside had the original fill excavated and replaced with 5,200 cubic yards of ¾ x No. 4 ESCS lightweight aggregate. During construction on the road base and supporting slope the remaining lane remained open to traffic. The sloped portion of the fill was coved with normal weight rip rap to prevent erosion of the lightweight fill. The outside lane was repaved and the highway opened back up to traffic.





Backfill Behind Sheetpile

Inerim Closure Structure*, 17th Street Canal, New Orleans, Louisiana*

4,900 cubic yards

When Hurricane Katrina caused a breach in the flood walls protecting the City of New Orleans in 2005, the U.S. Army Corps of Engineers began immediate emergency repairs to the entire flood control system before tackling the larger job of creating more robust protective structures throughout the metropolitan New Orleans area. One of the first repair projects was the reconstruction of the 17th Street Canal. The project consisted of constructing sheetpile cofferdams along the canal's route from Lake Ponchartrain to the Mississippi River. ESCS lightweight aggregate was specified for the fill material within the cofferdam cells, to minimize lateral earth pressures and reduce the depth to which the sheet piles were driven. The specifications required maximum in-place compacted densities of 65 pounds per cubic foot. The angle of internal friction was specified at a minimum of 40 degrees when measured in direct shear.

Prevention of Differential Settlement

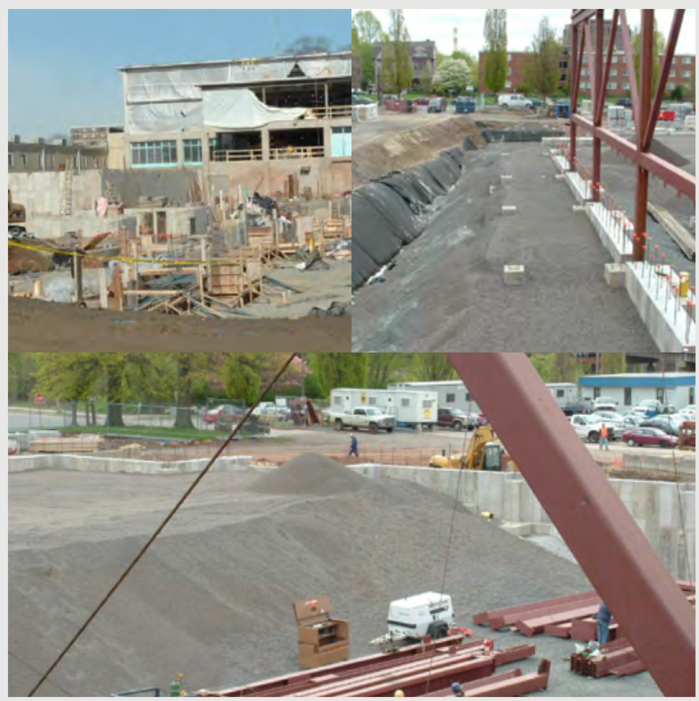
Hartford Public High School*, Hartford, Connecticut*

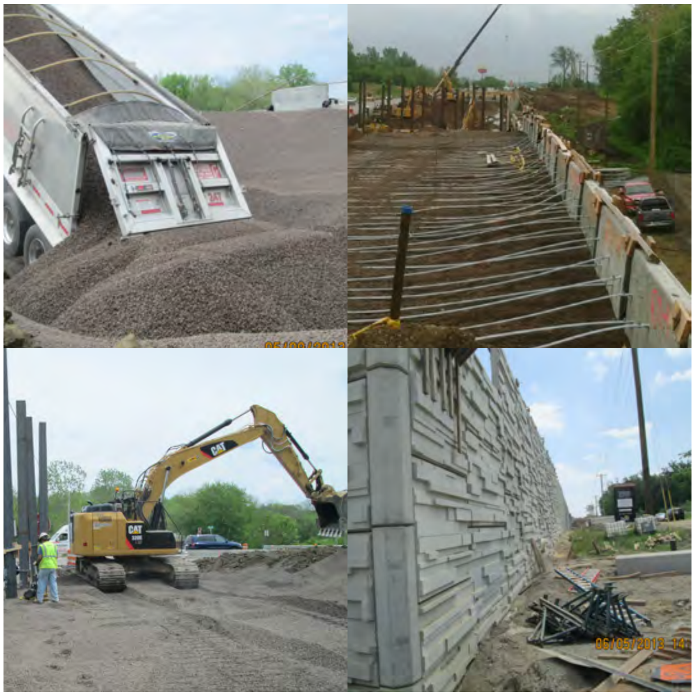
16,000 cubic yards

Founded in 1638, Hartford Public High School is the second oldest high school in the United States and has a long tradition of academic excellence. Over the school's 350+ years of existence a number of structures were utilized to educate the students. The most recent renovation/addition to the school took place in the early 2000's. The older portion of the school was given an extensive remodel and a large addition was attached to the existing structure. Because of issues with site conditions, differential settlement between the new and existing structures was a concern.

After evaluation of the options, geotechnical engineer, Haley & Aldrich, decided to use ESCS lightweight aggregate fill on portions of the project. The soft soil layers at the site did not provide adequate support for the weight of the proposed new construction. The designers were concerned that unacceptable settlement of the new addition would cause misalignment with the adjacent existing section of the school.

Approximately 16,500 cubic yards of ESCS was utilized because of its lower in-place compacted density. The in-place compacted density of the ESCS was one half of the density of a normal weight fill. Additionally ESCS fill allowed ease of placement around some of the complex foundation elements of the building. The renovation and expansion of the school has been serving the community since 2006.





Backfill Behind MSE Walls

***Indiana "Major Moves " Project, US 31 and 156th Street Intersection**, Carmel/Westfield, Indiana*

34,000 cubic yards

This portion of the Indiana "Major Moves" US Highway 31 redesign called for the construction of new southbound lanes while utilizing the existing lanes for northbound traffic. A new bridge and approaches would utilize MSE wall construction to eliminate the at-grade crossing with 156th Street. Buried gas pipelines running under the intersection required the use of a ESCS lightweight aggregate to mitigate a vertical loading issue with the new design.

Approximately 33 feet below the intersection, under the existing but newly redesigned northbound lanes, Panhandle Eastern Pipeline Company has existing gas lines that run diagonally (NE to SE direction) across US 31. The existing soil was removed and replaced with ESCS lightweight aggregate to alleviate increase load issue due to the new construction design. Aggregate deliveries (15 to 20 truck load per day at 23 to 25 ton each) tracked simultaneously with the MSE wall construction. An excavator and a small rubber track dozer were used to help place and compact the 12-inch lifts of lightweight aggregate. 20 HP vibratory plate compactors were also used along the walls where the excavator could not manage. The project used approximately 34,000 cubic yards of lightweight aggregate to back fill the north and south bound lanes, which included the area on top of the buried gas pipelines. The project was started in April of 2013 and was completed in October of the same year. The Westfield stretch of US 31 is now three lanes in each direction between 146th Street and SR 32.

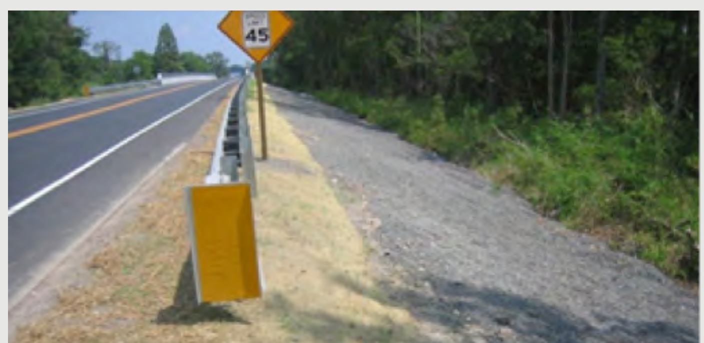
Bridge Approaches

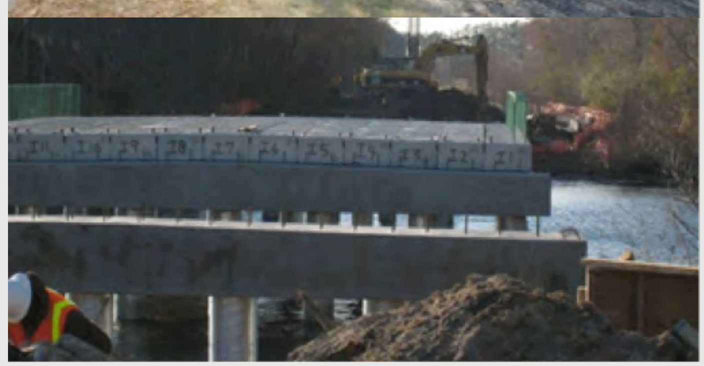
***Tranters Creek Bridge**, Washington, North Carolina*

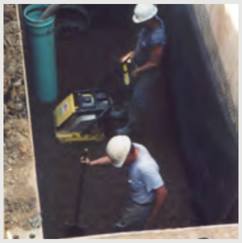
3,600 cubic yards

The North Carolina Department of Transportation designed a project to replace the Clarks Neck Road Bridge over Tranters Creek just outside Washington, NC. The project consisted of widening the existing embankment, raising the elevation one foot and lengthening the bridge 120 feet. The soils consisted of roadway embankment fill underlain by alluvial muck. The embankment fill was very loose to loose, silty fine to coarse sand. The alluvial muck was about 9 feet to 16 feet thick and generally showed SPT values of 2 to 4 blows per foot.

The area from station 16+25 to 19+98 on the west side of the bridge was undercut 2 feet and covered with an embankment stabilization fabric and backfilled to subgrade level with ESCS lightweight aggregate fill. About 3600 cubic yards of lightweight aggregate fill was used for the project.







Fill in Pipe Trench

***Northfield Sanitary Sewer**, Northfield Center, Ohio*

2,000 cubic yards

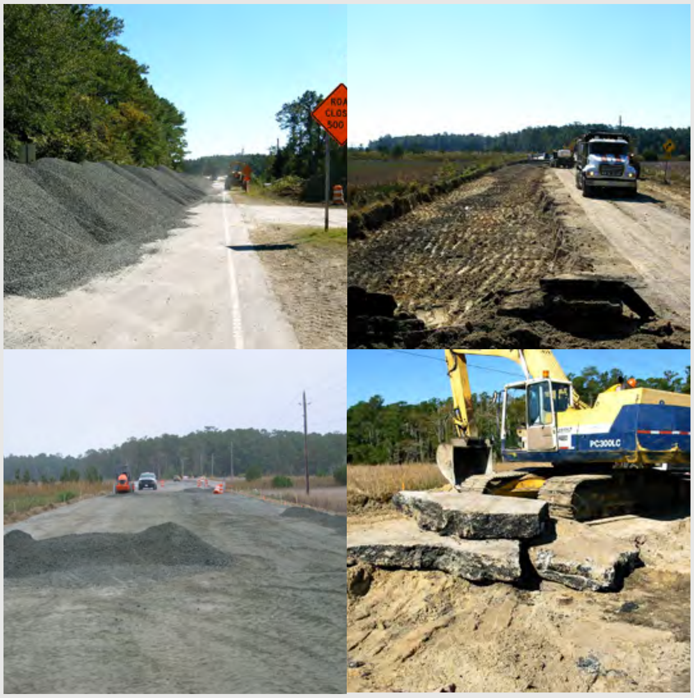
In the spring of 2000, Wingfoot Rental and Development received the contract from Summit County Ohio to dismantle an existing pump station and replace the sanitary system with a gravity-fed line. The new 24-inch sewer line was placed at a depth of 28 – 30 feet below grade with a 3-foot undercut.

The initial design utilized traditional limestone backfill. The right of way for the project passed through an area of unstable marshy soil. When the initial phases for this project were inspected, problems were spotted. The inspection revealed that there was settlement in the line when the examination camera went under water indicating a low spot. In the past when this occurred, a pile and cradle system was designed and installed.

After evaluation of the site it was determined that 6,000 feet of the 10,000-foot project would need to be placed on piles. This type of construction is very costly.

An alternative to help keep the costs under control was considered. This solution incorporated the use of ESCS lightweight aggregate, geotechnical grid and geotechnical fabric in place of the pile and cradle system. Because of the expanded shale's in-place densities of less than 60 pounds per cubic foot, the poor soil condition at the jobsite supported the new pipe and lightweight backfill. This solution eliminated the need for the costly pile and cradle system and allowed the contractor to complete the project much quicker than the more expensive alternative.

According to John Smith of Wingfoot Rental & Development the pile and cradle system would install at a rate of 40 linear feet of line per week while the lightweight backfill and geosynthetics system installed at a rate of 100 linear feet per week. This provided a significant savings on this project. John estimates that using expanded shale on this project provided a savings of $4.5 million.



Roadbase

NC Rte. 133 Repairs to Approaches at Liliput Creek Bridge, Brunswick County, North Carolina

3,125 cubic yards

North Carolina Route 133 in rural Brunswick County crosses a tributary of the Cape Fear River near the historic Orton Plantation. The approaches on the bridge that carries NC 133 over Liliput Creek had settlement problems that required an unusual amount of maintenance. To repair the approaches it was determined that they must be excavated approximately 24" below subgrade; a geo-fabric installed; and the subgrade returned to elevation using lightweight aggregate fill. In August 2005 APAC-Carolina, Inc. was awarded the contract to effect these repairs. Excavation of the subgrade and delivery and placement of lightweight aggregate fill material began in October 2005 and was completed in November 2005. At the time the approaches were rebuilt, the contractor found repaired pavement over 9 inches thick that had contributed to the settlement. Approximately 3,125 cubic yards of lightweight fill were placed in the approaches and the roadway was repaved, completing the repair in early 2006. The repaired approaches have now been in service for many years without further issues.

ESCS Advantages

Design

- Cost Effective
- Water Insoluable
- Chemically Inert
- High Durability
- Increased Stability
- Free Draining
- Thermal Insulation
- Reduced Over Turning Forces
- High Internal Friction Angle
- Reduced Dead Loads
- Acid Insoluable
- High Strength
- Controlled Gradations
- Controlled Settlement
- Reduced Lateral Forces

Placement

- No Special Job Site Equipment Needed
- Readily Available
- Easy to Handle and Install
- Can Be Placed in Any Weather
- No Waiting Between Placing Lifts
- Lower Transportation Costs
- Easily Compacted

Specifying ESCS Geotechnical Fill

Consult your expanded shale, clay or slate producer, preferably during the conceptual design phase of a project, for precise information on aggregate grading, bulk density (unit weight), in-place compacted density, friction angle, thermal conductivity, and placement method. The ESCS producer often has the ability to offer a variety of grading options. Use this versatility to specify the optimum material for any given application. As with ordinary aggregates, the engineering properties of ESCS vary depending on aggregate sources and grading.

Guide Specifications for Lightweight Geotechnical Applications

Aggregate

Lightweight aggregate shall be Expanded Shale, Clay or Slate (ESCS) produced by the rotary kiln process and meeting the requirements of ASTM C 330. Lightweight aggregate shall have a proven record of durability, and be non-corrosive, with the following properties:

Aggregate Physical Properties

- A1 Soundness Loss: The maximum soundness loss shall be 30% when tested, with 4 cycles of Magnesium sulfate, in accordance with AASHTO T 104.
- A2 Abrasion Resistance: The maximum abrasion loss shall be 40% when tested in accordance with ASTM C 131.
- A3 Chloride Content: The maximum chloride content shall be 100 ppm.
- A4 Grading: Aggregate grading comes in a wide variety of sizes and is specified based on performance needs. Grading shall be tested in accordance with ASTM 136. (See Comment No. 1)

Project Performance Specification

- B1 In-place bulk density (unit weight): The maximum in-place compacted moist density shall be _______ lbs/ft3 when tested in accordance with the method specified by the engineer. (See Comment No. 2)
- B2 Stability (Phi angle, Φ): The minimum angle of internal friction Φ shall be _______ degrees when tested in accordance with the method specified by the engineer. (See Comment No. 3)

Construction

- C1 Method of Construction: Lightweight fill shall be placed in uniform layers. The actual lift thickness, and exact number of passes by equipment used will be determined by the engineer, depending on the project requirements (i.e., stability, compaction, density). In confined areas vibratory plate compaction equipment shall be used (5 hp to 20 hp) with a minimum of two passes in 6″ lifts for a 5 hp plate and 12″ lifts for a 20 hp plate. The contractor shall take all necessary precautions when working adjacent to the lightweight fill to ensure that the material is not over compacted. Construction equipment, other than for placement and compaction, shall not operate on the exposed lightweight fill.
- C2 Aggregate loose bulk density (unit weight): The maximum aggregate loose bulk density _______ shall be ______ lbs/ft3 when tested in accordance with ASTM C 29. (See Comment No. 4)

Comments

1. Grading: ESCS aggregates are available in a wide variety of grading, therefore it is essential the specifier contact the ESCS supplier for the gradings that are available in a given location. Some common gradings are 3/4" to No 4, 1/2" to No. 4, 3/8" to No. 8, 3/8" to 0, 2" to 3/4", 2" to 0 or blends of these. ESCS aggregate suppliers can be found on ESCSI's website at www.escsi.org.

2. Several methods have been used to determine the in-place moist bulk density (unit weight) of a given aggregate, therefore contact the ESCS producer for recommendation on local practices. The following methods have proven performance:

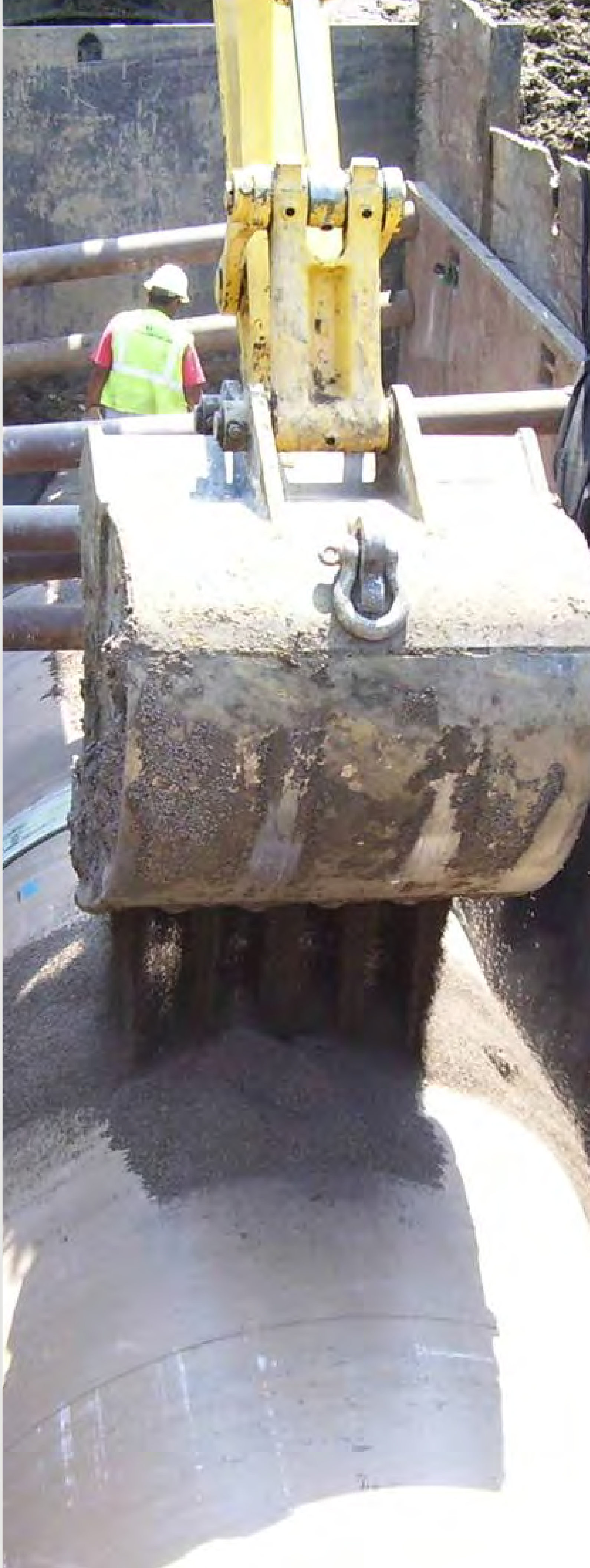
The lightweight aggregate producer shall submit verification of a compacted moist density of less than _______lb/ft3 when measured by a one point proctor test conducted in accordance with a modified version of ASTM D 698 "Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort." Because of the cohesionless nature of coarse lightweight aggregate, the standard shall be modified as follows: The aggregate sample shall be placed in a 0.5 cubic foot bucket at the moisture content that the aggregate will be delivered to the jobsite. The sample shall be placed in three equal layers and compacted by dropping a 5.5 pound rammer from a distance of 12 inches 25 times on each layer (AASHTO T-99 modified as above).

3. ESCS Lightweight Aggregate has been tested by both Direct Shear and Triaxial test methods. With either method, the phi angle will vary in both ordinary and ESCS fill, depending on test procedure, aggregate grading, particle angularity, amount of compaction and amount of consolidating stress applied during the test. Design and specify the minimum phi angle appropriate for the project design and material(s) that are contemplated for use in the project. Contact the ESCS supplier(s) for specific properties of their materials.

Direct Shear: The minimum angle of an internal friction shall be tested in accordance with ASTM D 3080 on a saturated representative sample (with particles larger than 0.75 inch removed) and tested in a round or square shear box that is a minimum of 12 inches across. Follow the procedure in D 3080 or shear the box at a rate of 0.01 inches per minute at normal loads of 250, 500 and 1,000 pounds per square foot.

4. For quality control and shipment quantities, the purchaser and supplier should agree on a maximum delivered loose bulk density (unit weight).

5. To convert bulk density (unit weight) in lb/ft3 to metric kg/m3, multiply by 16. To convert inches (in) to millimeters (mm) multiply by 25.4.



General Engineering Properties of ESCS ¾" to No. 4 Aggregate Grading

Aggregate Property	Measuring Method	Test Method	Commonly Used Specifications for ESCS	Typical Values for ESCS Aggregate	Typical Design Values for Ordinary Fills
Soundness Loss	Magnesium Sulfate	AASHTO T 104	<30%	<6%	<6%
Abrasion Resistance	Los Angeles Abrasion	ASTM C 131	<40%	20 - 40%	10 - 45%
Chloride Content	Chloride Content of Soils	AASHTO T 291	<100 ppm	10 - 70 ppm	
Grading	Sieve Analysis	ASTM C 136	Comment No. 1	Comment No. 1	
Compacted In-Place Bulk Density (Unit Weight)	Density Test	Comment No. 2	<70 lb/ft^3	40 - 65 lb/ft^3 moist	100 - 130 ibs/ft^3
Stability (Phi Angle, Φ)	Direct Shear Test, Consolidated, Drained Triaxial-Consolidated Drained	ASTM D 3080 Comment No. 3 Corps of Engineers EM 1110-2-1906 Appendix X Comment No. 3	Comment No. 3	35° - 45° +	30° - 38° (fine sand - sand & gravel)
Loose Bulk Density (Unit Weight)	Loose	ASTM C 29	Dry <50 lb/ft^3 Saturated <65lb/ft^3	Dry 30 - 50 lb/ft^3	89 - 105 lb/ft^3
pH	pH Meter	AASHTO T 289	5 - 10	7.0 - 10	5 - 10

Comments listed on previous page.

ESCSI
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www.escsi.org

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