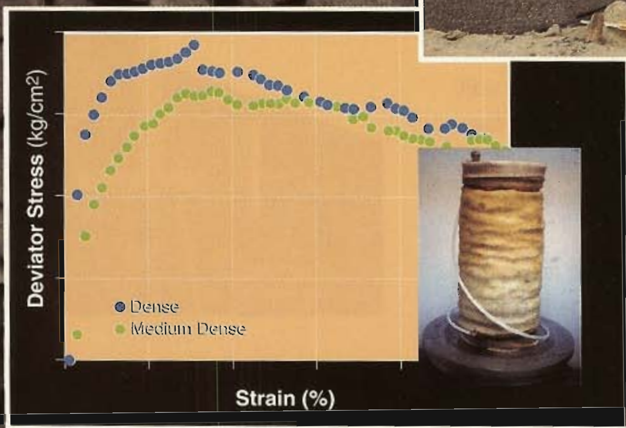


Norlite®

Lightweight Aggregate for Geotechnical Applications

Design Advantages...

- provides cost-effective solutions
- reduces loads
- controls settlements
- increases stability
- provides free drainage
- possesses high angle of internal friction
- provides thermal insulation

Placement Advantages...

- requires no special job site equipment
- allows all-weather placement
- eliminates waiting between placing lifts

Other Applications

- slope stabilization
- subgrade improvements
- gas ventilation for landfills

***Norlite**, an expanded shale aggregate, is produced by heating Normanskill shale in a rotary kiln at temperatures exceeding 2000°F (1100°C). During this process, entrapped gases expand, creating nonconnecting air cells in the material. The expanded shale is then crushed, sized, and sorted. The manufacturing process eliminates impurities and results in a structurally sound product that, due to its porous structure, possesses less than half the weight of natural aggregates.*

Suggested Norlite Specifications for Lightweight Geotechnical Applications

Materials

Lightweight aggregate fill shall be Norlite or approved rotary kiln substitute meeting the requirements of ASTM C-330. No by-product slags, cinders or by-products of coal combustion shall be permitted. Lightweight aggregate shall have a proven record of durability, as determined by ASTM C-88 and ASTM C-131, and be non-corrosive, as determined by CAL DOT 422 with the following physical properties:

A. Delivered Gradation:

Sieve Size		% Passing
1"	(25.0mm)	100
3/4"	(19.0mm)	90 - 100
3/8"	(9.5mm)	10 - 50
#4	(4.75mm)	0 - 15

B. The dry loose density shall be less than 50 pcf (801 kg/m^3).

C. The maximum in situ density (moist, surface dry) shall be less than 60 pcf (961 kg/m^3). The minimum compacted dry density shall be equal to 65% relative density as determined by ASTM D-4253 and D-4254, or as otherwise specified by the engineer.

D. The maximum soundness loss when tested with 5 cycles of magnesium sulfate shall be 10% (ASTM C-88).

E. The maximum chloride content (CAL DOT 422) shall be 100 ppm.

F. The minimum strength of loosely placed material, as determined from drained triaxial tests, shall equal that of cohesionless soil with an angle of internal friction of 36°. Minimum strength of material compacted to 65% relative density shall equal that of a cohesionless soil with an angle of internal friction of 40°.

Method of Construction

Lightweight fill can be 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, unit weight) and equipment used. The contractor shall take all necessary precautions during construction activities in operations on or adjacent to the lightweight fill to ensure that the material is not over-compacted. Construction equipment, other than for compaction, shall not operate on the exposed lightweight fill.

Earth Retaining Structures

Problem 1

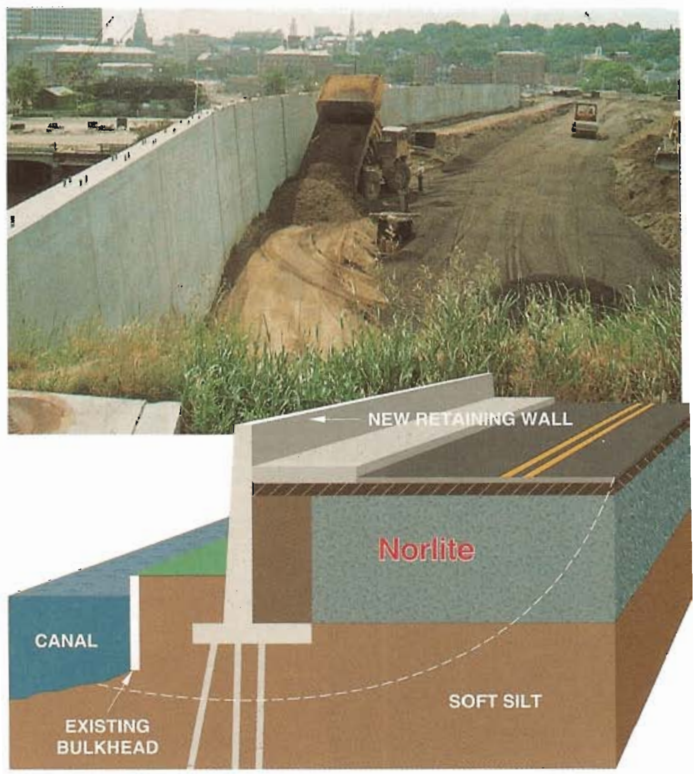
Low Safety Factor against Deep-Seated Failure

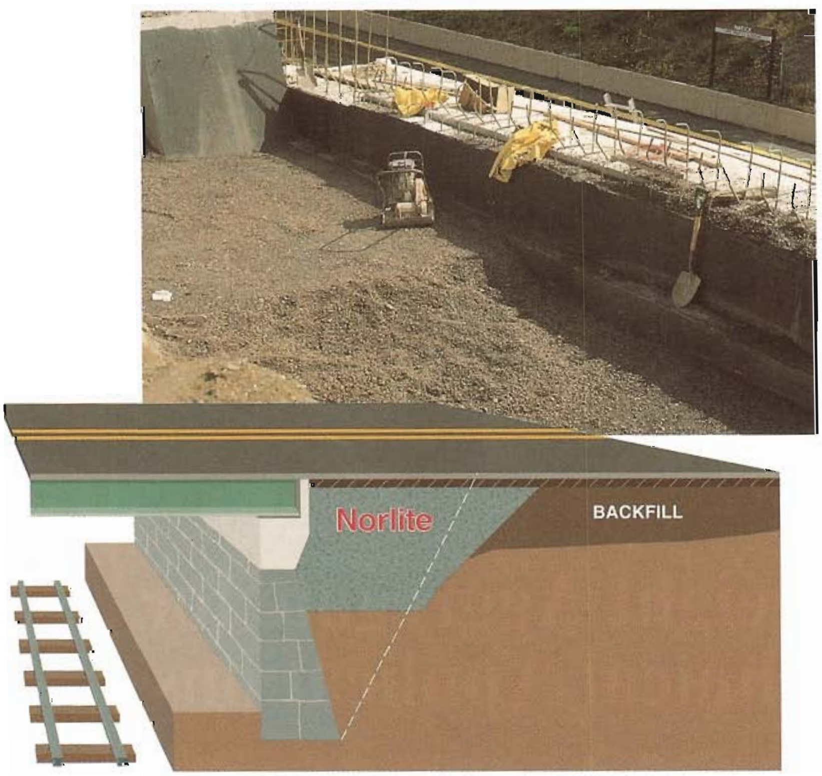
Design of the Capital Center Project in Providence, Rhode Island included a pile-supported 35' high cantilever retaining wall adjacent to the Providence River. The weight of the proposed structure, including the backfill soil, would significantly increase loads on the underlying soft silt. The designers wanted to avoid triggering a deep-seated failure of an old bulkhead along the river bank.

Solution

Engineers specified over 10,000 cubic yards of *Norlite* Lightweight Aggregate for placement behind the cantilever wall. Because of its light weight, *Norlite* reduced the loads on the foundation soils and behind the retaining wall, and increased the safety factor against deep-seated failure to acceptable levels.

In another application, 5,500 cubic yards of Norlite maintained stability of an existing bulkhead along Long Wharf in Boston.





Problem 2

Increased Lateral Loads and Overturning Moments

MBTA's renovations to a railway bed in Natick, Massachusetts required increasing the bridge clearance. This would involve raising both abutments and adjacent elevation. The increased lateral loads and overturning moments could have damaged the bridge's old masonry abutments.

Solution

Norlite Lightweight Aggregate was used to both raise the adjoining area to the desired elevation and to replace some of the heavier existing backfill. Because *Norlite* aggregate is lighter than natural soils, it maintained the same lateral loads and overturning moments behind the abutments.

Soft Ground Improvements

Problem 1

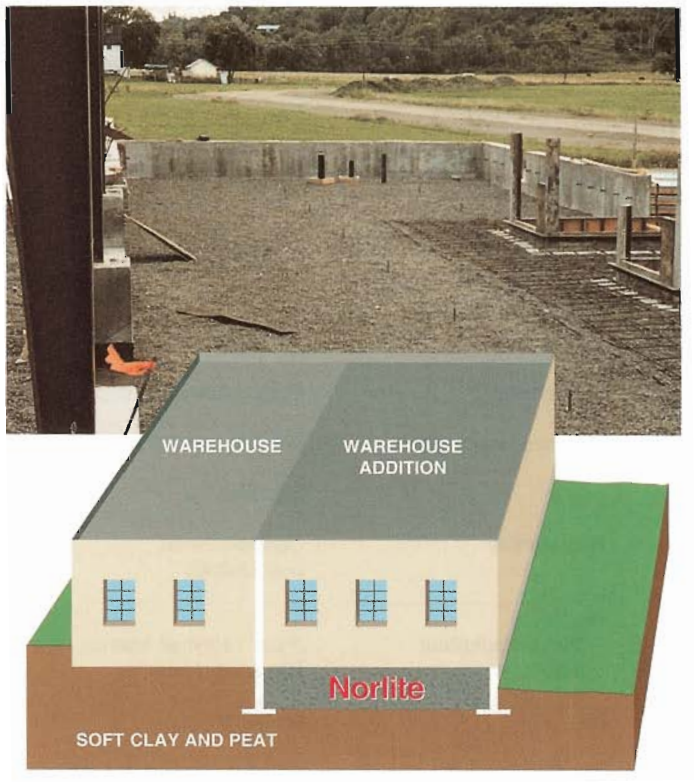
Excessive Differential Settlements

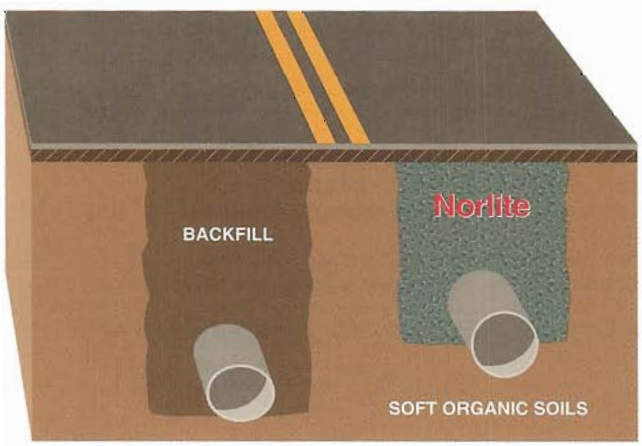
The underlying soils at the Vermont Cheese Factory warehouse in Hinesburg, Vermont consisted of soft clay and peat. Engineers wanted to avoid structurally damaging differential settlements between the existing warehouse and a proposed new addition.

Solution

Several feet of existing soft soils were replaced with *Norlite* Lightweight Aggregate. Because the aggregate weighs only half as much as the existing soil, *Norlite* reduced the total foundation load of the new structure and kept differential settlements well within tolerable limits.

Engineers have used *Norlite* in soil replacement techniques for many years on a variety of structures, including the Massachusetts Institute of Technology Arts and Media Facility.





Problem 2

Potential Settlements, Pipe Damage

A 12" utility line in the town of New London, Connecticut had to be placed across a swampy, two-acre site. Settlement in the soft organic soils induced by the trench backfill could damage the pipe.

Solution

Norlite Lightweight Aggregate was used to solve several problems. The aggregate limited the amount of ground settlement to levels that the utility line could safely tolerate and its light weight reduced loads on the pipe. In addition, the aggregate's thermal insulating properties provided protection from freezing.

Material Properties of Norlite Lightweight Aggregate

Property	Measuring Method	Test Method	Norlite	Natural Granular Fill
Dry Loose Density	Minimum Density Test	ASTM D-4254	40.2 pcf (644 kg/m^3)	89.0 pcf[1] (1426 kg/m^3)
Dry Compacted Density	Maximum Density Test	ASTM D-4253	45.5 pcf (729 kg/m^3)	146.0 pcf[1] (2339 kg/m^3)
Strength (ϕ)	Triaxial Test	Consolidated Drained	42°-53°[2] (medium dense)	36°-42°[3] (medium dense)
Gradation	Sieve Analysis	ASTM C-136	*See Material Specs*	
Soundness	Magnesium Sulfate	ASTM C-88	5.1%	<6%
Abrasive Resistance	Los Angeles Abrasion	ASTM C-131 (B grading)	32%	30-45%
	Modified	FM 1-T 096	21%	
Permeability	Constant Head (i=0.29-0.43)	ASTM D-2434	13.4-15.0 cm/sec	0.016 cm/sec[4]
Resistivity				
- Field (stockpiled)	"Four Terminal" Method	G-57	5.3 x 10^5 ohm-cm	5-10 x 10^5 ohm-cm[5]
- Lab	Resistivity Meter	CAL DOT 643	32,234 ohm-cm	
pH	pH Meter	CAL DOT 643	7.4	4-6.5[6]
Chloride Content	Chloride Content of Soils	CAL DOT 422	<5-46 ppm	
Sulfate Content	Sulfate Content of Soils	CAL DOT 417	146 ppm	
Thermal Conductivity	Guarded Hot Plate	ASTM C-177	.98 Btu/hr ft^2 °F/in[7] (.141 W/m °C)	9-12 Btu/hr ft^2 °F/in[8] (1.35-1.7 W/m °C)

[1] Silty Sand & Gravel from T. W. Lambe and R. V. Whitman, *Soil Mechanics* (New York: John Wiley & Sons, Inc., 1969), 31.

[2] Strength envelope defined by ϕ = f(confining stress). Range of ϕ values shown represent confining stresses from 2.05 tsf (196 kPa) to 0.25 tsf (24 kPa), respectively. Contact Norlite for additional strength information.

[3] Sand & Gravel from T. W. Lambe and R. V. Whitman, *Soil Mechanics* (New York: John Wiley & Sons, Inc., 1969), 149.

[4] Sandy Gravel from T. W. Lambe and R. V. Whitman, *Soil Mechanics* (New York: John Wiley & Sons, Inc., 1969), 290.

[5] Boulders, Gravels, Dry Sands from A. Rico Rodriguez, H. del Castillo and G. F. Sowers, *Soil Mechanics in Highway Engineering* (Clausthal-Zellerfeld Trans Tech Publications, 1988), 114.

[6] Humid Forest Soils from L. M. Thompson and F. R. Troeh, *Soil and Soil Fertility* (New York: McGraw-Hill Publishing , Co.), 169.

[7] Conductivity for 40 pcf (641 kg/m^3) dry lightweight aggregate from Rudolph C. Valore, Jr., *The Thermo-physical Properties of Masonry and its Constituents, Part 1, Thermal Conductivity of Masonry Materials*

[8] Conductivity for 120 pcf (1922 kg/m^3) Sand with Clay & Gravel from Rudolph C. Valore, Jr., *The Thermo-physical Properties of Masonry and its Constituents, Part 1, Thermal Conductivity of Masonry Materials*

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