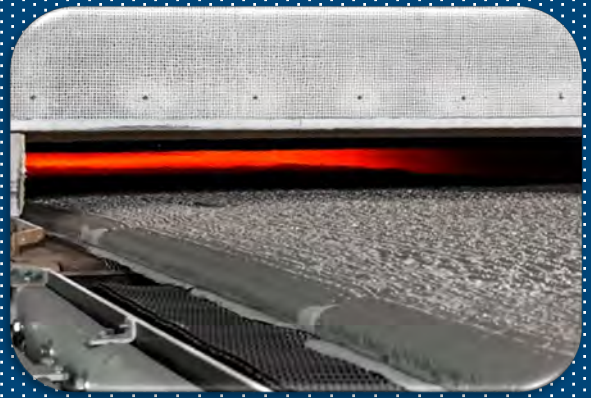


FOAMED GLASS AGGREGATE

Ultra Lightweight Fill

AERO® AGGREGATES

NESMEA
North Eastern States' Materials Engineers Association

Theresa Andrejack Loux, Ph.D., P.E.

October 16th, 2018
Atlantic City, NJ

Outline

FOAMED GLASS AGGREGATE

- Introduction
- History
- Manufacturing
- Material Properties
- Installation
- Applications
- Brief Case Studies

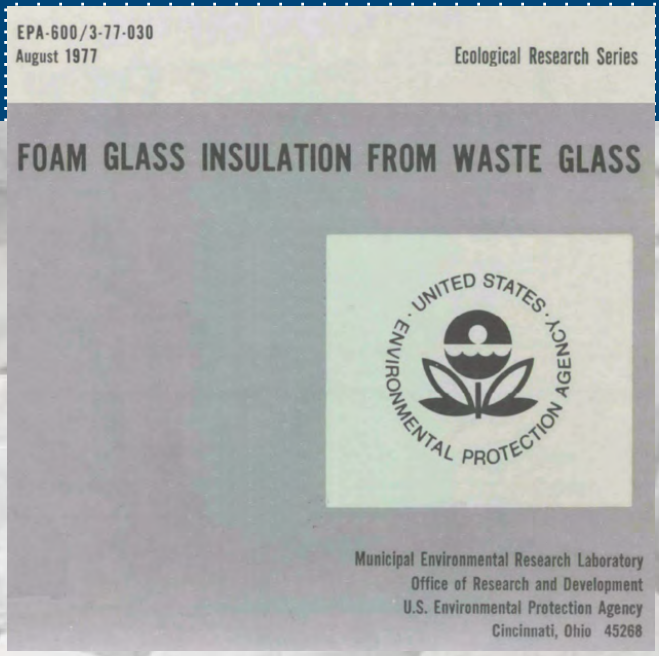
Introduction

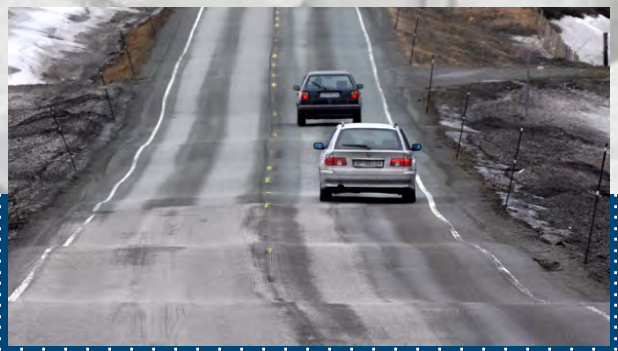
LIGHTWEIGHT FILL ALTERNATIVES

- Geofoam (1-2 pcf)
- Foamed Glass Aggregate (8-25 pcf)
- Foamed Concrete (20-45 pcf)
- Expanded Shale or Clay (45-65 pcf)

History

- US EPA – Insulation – 1977
- Developed in Germany – early 1980s
- Technology taken to Norway – early 1990s
- Thermal barrier for roadways
- Led to Lightweight applications
- Growth through Scandinavia
  - Geotechnical Applications
    (Norway, Sweden, Finland)
- Germany & Switzerland
  - Thermal Insulation
  - Lightweight Concrete

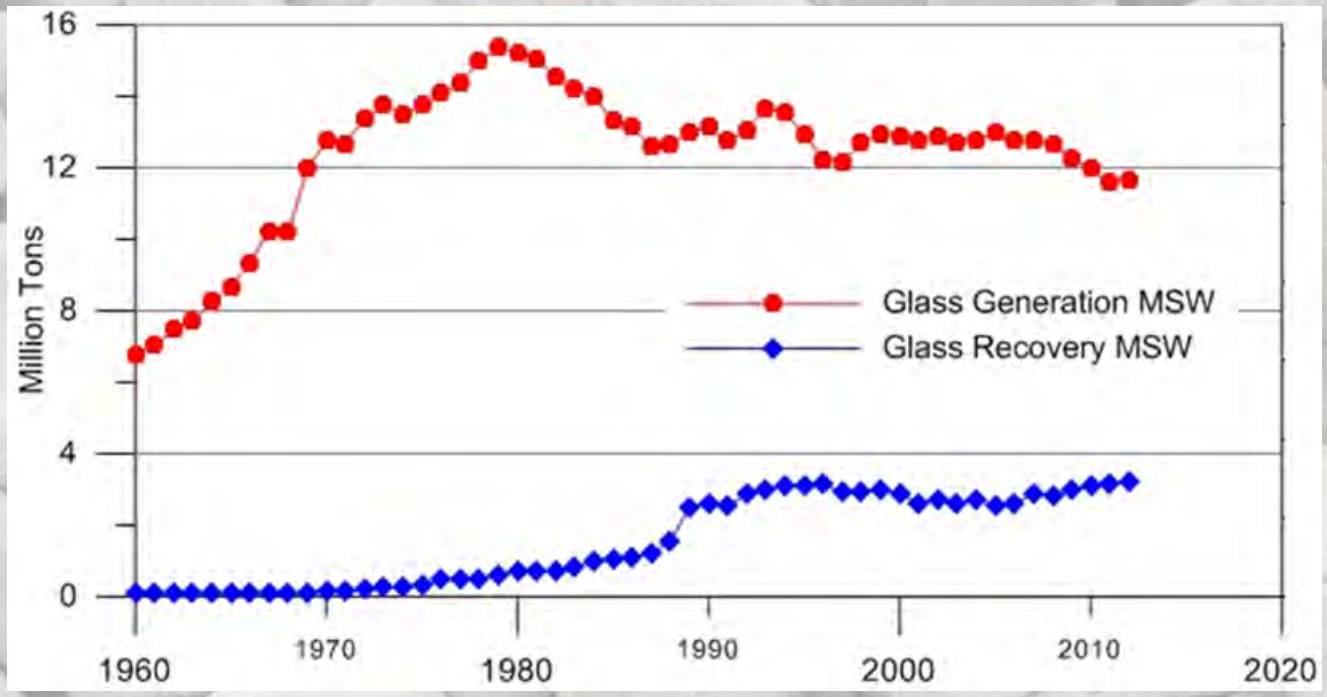




Glass Recovery in the U.S.A.

Total Glass:
11.6 MTon/yr

Containers:
9.4 MTon/yr



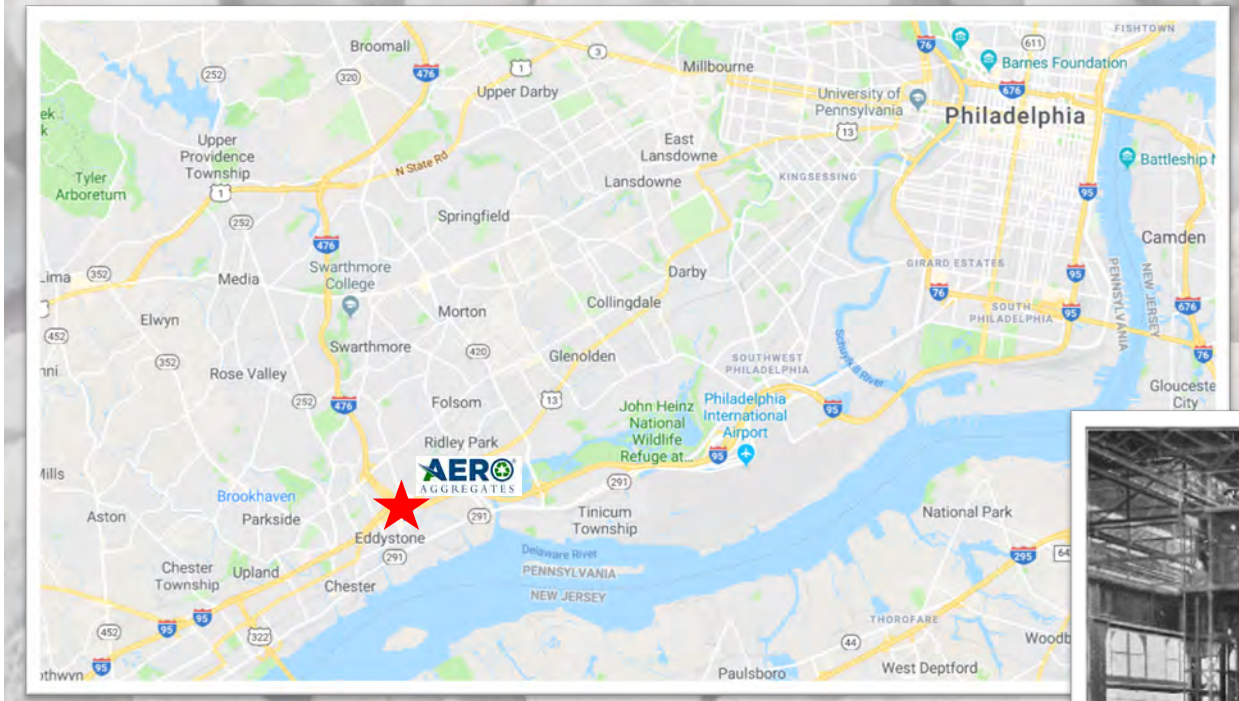
US EPA

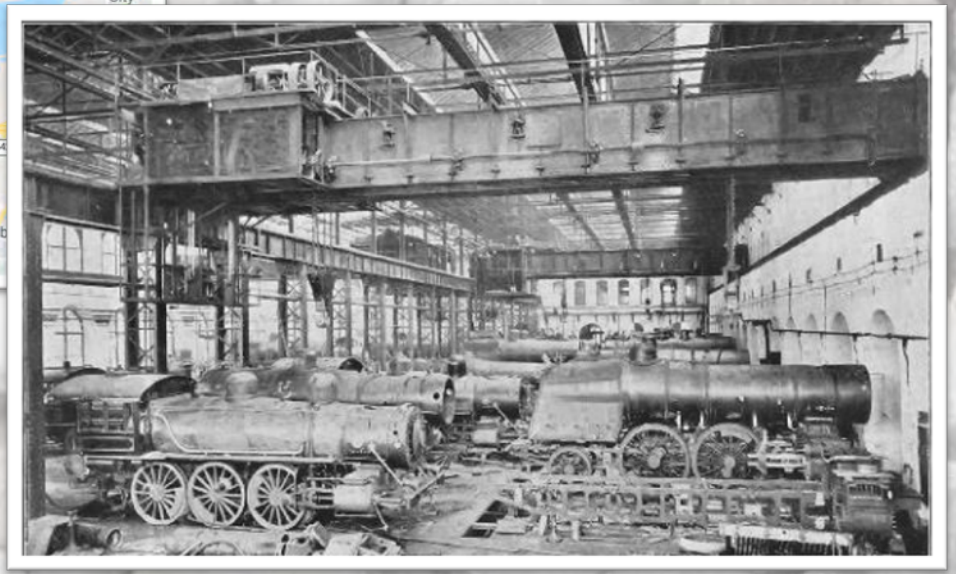
… Only ~31%

Made from 100% Post-Consumer Glass

140 MILLION GLASS BOTTLES RECYCLED /year starting in 2018

Manufacturing

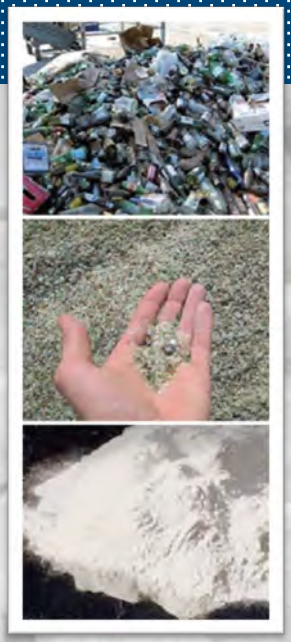




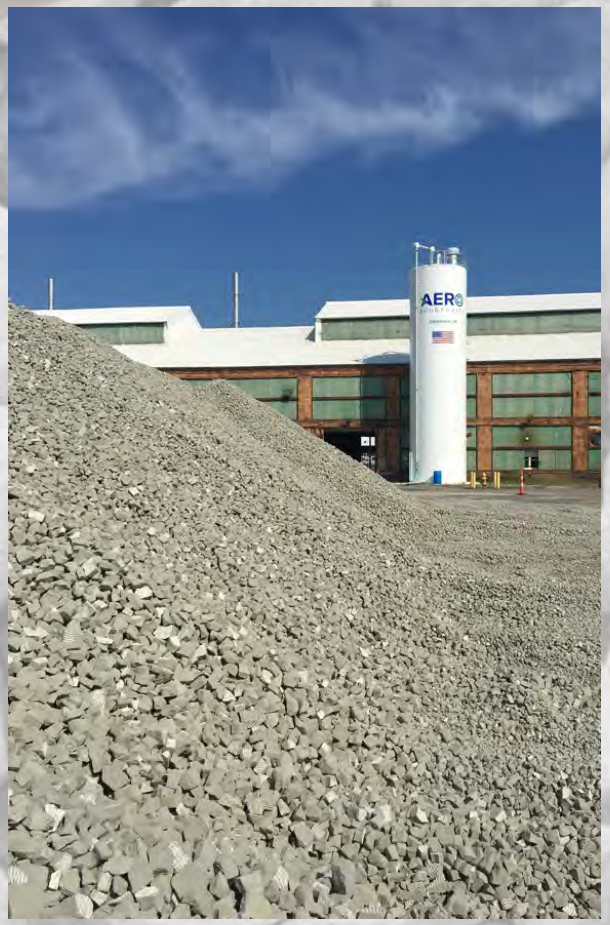
10 acre site/ 97,000 sq.ft. building

The Process …

- Recycled Glass …
  Any Color, Any Size
- Clean Glass Cullet
- Mill into Fine Powder
- Mix w/ Foaming Agent
- Process through Kiln
  & Conveyor
- Stockpile



The Process …



Closed vs. Open Cell

Closed Cell

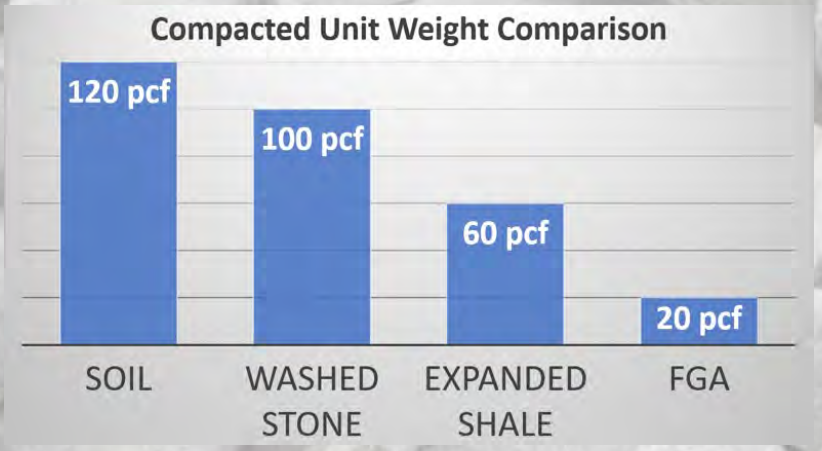
Wet Process

Dry Process ✓

Open Cell

Material Properties – G15

Property	Units	Value
Particle Size	in	0.4 – 2.4
Loose Bulk Density (dry), max	pcf	15
Compacted Density (moist)	pcf	15-23
Thermal Conductivity	W/mK	0.11 dry/ 0.15 wet
Peak Friction Angle	degrees	55



Daily Quality Control

Determine Dry Bulk Density

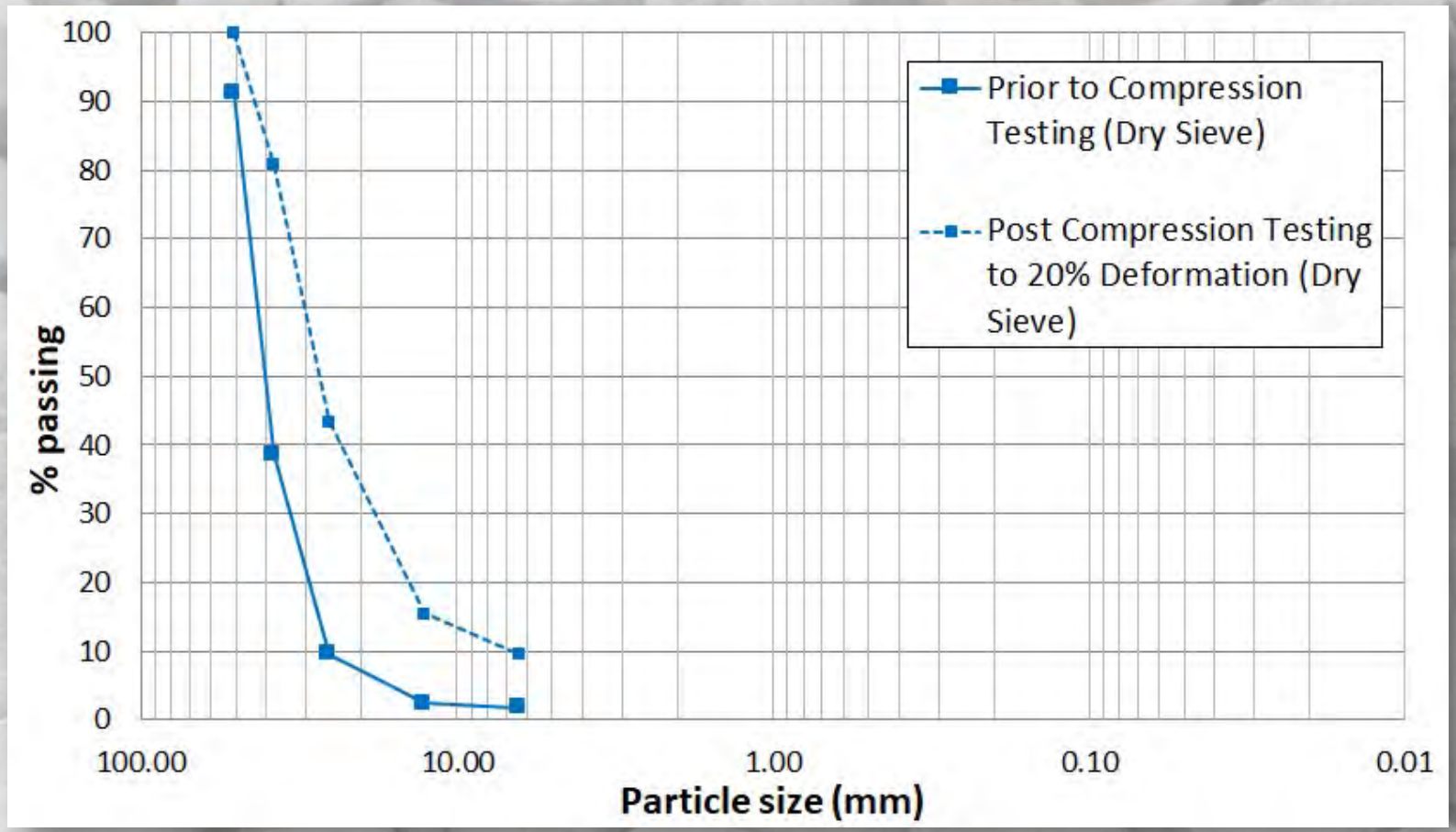
< 15 pcf
(avg ~13.5)

Determine Compressive Strength

@ 20%
> 15,000
psf

Modified version of the European Standard EN 1097-11, "Tests for mechanical and physical properties of aggregates, Part 11: Determination of compressibility and confined compressive strength of lightweight aggregates".

Gradation



GP per USCS

Moisture Content and Buoyancy

Moisture Content

- Adsorption of Water to Surface – **Closed Cell**
- Moist conditions - Typical 6% by volume (additional 3.75 pcf)
- Can be higher if submerged

Buoyancy

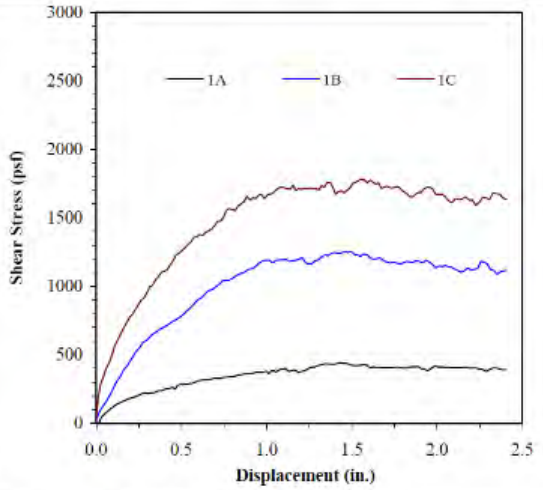
- Testing completed – Schnabel Engineering, West Chester
- Using **-15 pcf** as a typical buoyant unit weight, you would need about 1 foot of "typical" fill (120 pcf) to offset the uplift on 8 feet of submerged FGA (8:1 ratio…..120/15)

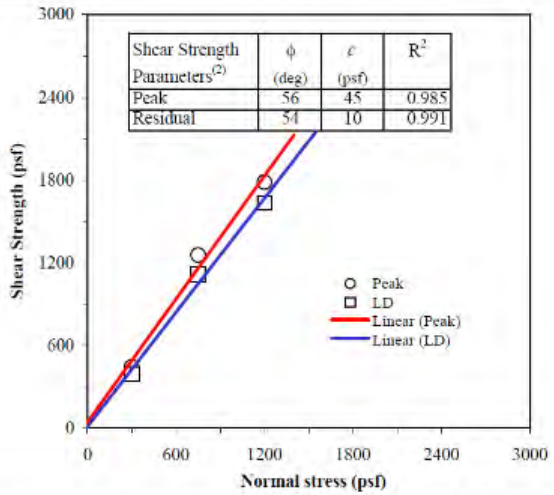
Also: Durability Tested

Direct Shear

DREXEL UNIVERSITY - CIVIL, ARCHITECTURAL AND ENVIRONMENTAL ENGINEERING
DIRECT SHEAR TESTING (ASTM D 3080 MODIFIED)

Test Series No. 1: Lightweight aggregate (LWA-FG) lightly compacted under dry conditions



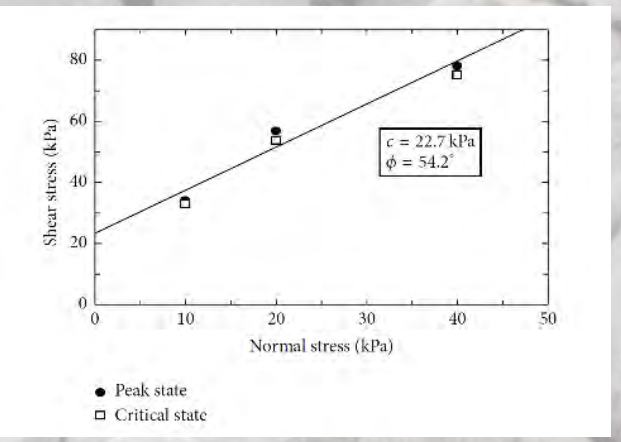


Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	Soaking (psf)	Soaking (hour)	Consolidation Step 1 (psf)	Step 1 (hour)	Step 2 (psf)	Step 2 (hour)	Step 3 (psf)	Step 3 (hour)	Soil Compaction γ_m (pcf)	ω_i (%)	ω_f (%)	Shear Strength τ_P (psf)	τ_R (psf)	Failure Mode
1A	12 x 12	300	0.04	-	-	-	-	-	-	-	-	15.3			444	392	(1)
1B	12 x 12	750	0.04	-	-	-	-	-	-	-	-				1255	1116	(1)
1C	12 x 12	1200	0.04	-	-	-	-	-	-	-	-				1784	1634	(1)

NOTES:
(1) Shear failure was forced to occur internally through the soil specimen at the predetermined plane between the upper and lower shear box during each test.
(2) The reported total-stress parameters of friction angle and cohesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The residual shear strength was calculated using the shear force measured at the end of the test.

SGI TESTING SERVICES, LLC

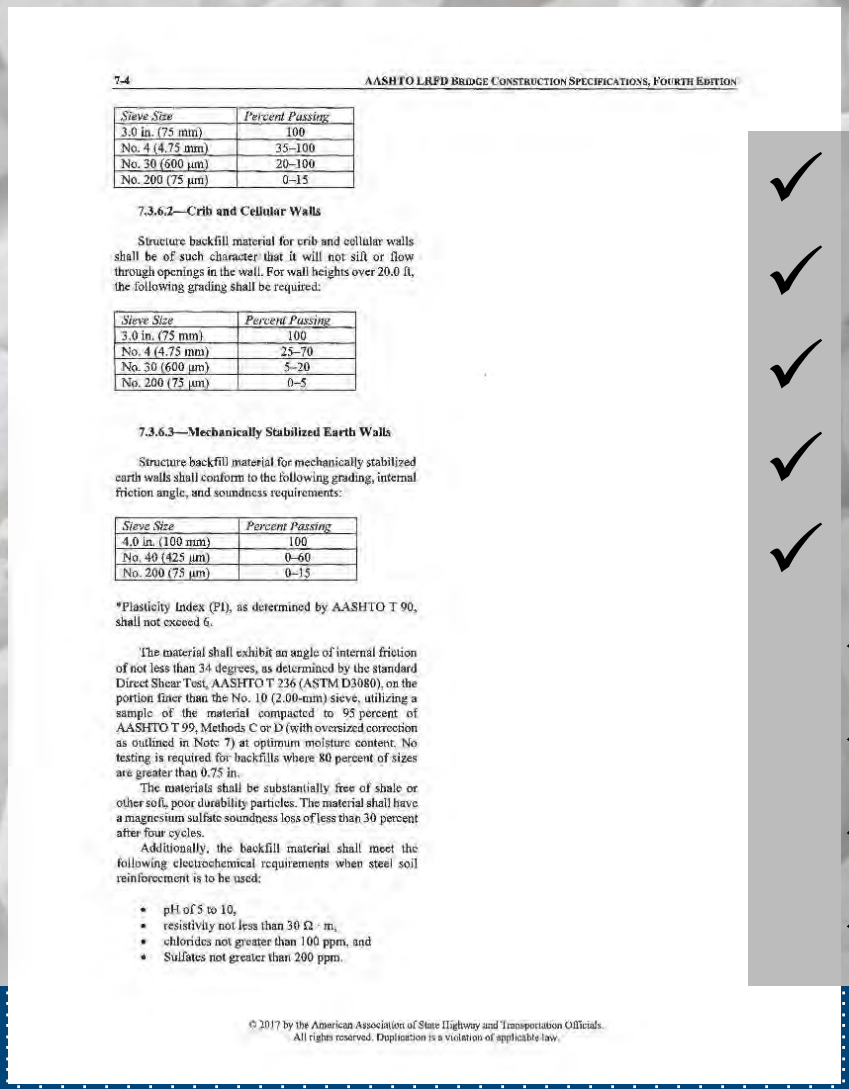
DATE REPORTED:	4/28/2016
FIGURE NO.	C-1
PROJECT NO.	SGI16023
DOCUMENT NO.	
FILE NO.	



Arulrajah et al., 2015. "Evaluation of Interface Shear Strength Properties of Geogrid Reinforced Foamed Recycled Glass Using a Large-Scale Direct Shear Testing Apparatus." ***Advances in Material Science and Engineering.***

MSE Wall Backfill

AASHTO LRFD Bridge Construction Specifications



7-4 AASHTO LRFD BRIDGE CONSTRUCTION SPECIFICATIONS, FOURTH EDITION

Sieve Size	*Percent Passing*
3.0 in. (75 mm)	100
No. 4 (4.75 mm)	35–100
No. 30 (600 μm)	20–100
No. 200 (75 μm)	0–15

7.3.6.2—Crib and Cellular Walls

Structure backfill material for crib and cellular walls shall be of such character that it will not sift or flow through openings in the wall. For wall heights over 20.0 ft, the following grading shall be required:

Sieve Size	*Percent Passing*
3.0 in. (75 mm)	100
No. 4 (4.75 mm)	25–70
No. 30 (600 μm)	5–20
No. 200 (75 μm)	0–5

7.3.6.3—Mechanically Stabilized Earth Walls

Structure backfill material for mechanically stabilized earth walls shall conform to the following grading, internal friction angle, and soundness requirements:

Sieve Size	*Percent Passing*
4.0 in. (100 mm)	100
No. 40 (425 μm)	0–60
No. 200 (75 μm)	0–15

*Plasticity Index (PI), as determined by AASHTO T 90, shall not exceed 6.

The material shall exhibit an angle of internal friction of not less than 34 degrees, as determined by the standard Direct Shear Test, AASHTO T 236 (ASTM D3080), on the portion finer than the No. 10 (2.00-mm) sieve, utilizing a sample of the material compacted to 95 percent of AASHTO T 99, Methods C or D (with oversized correction as outlined in Note 7) at optimum moisture content. No testing is required for backfills where 80 percent of sizes are greater than 0.75 in.

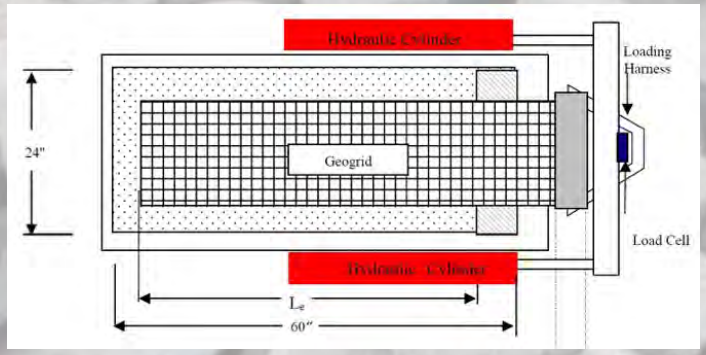
The materials shall be substantially free of shale or other soft, poor durability particles. The material shall have a magnesium sulfate soundness loss of less than 30 percent after four cycles.

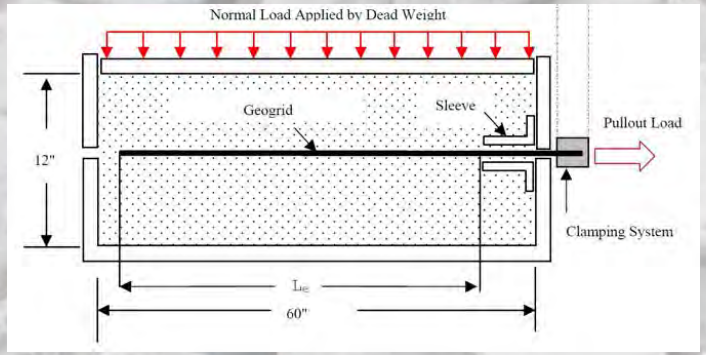
Additionally, the backfill material shall meet the following electrochemical requirements when steel soil reinforcement is to be used:

- pH of 5 to 10,
- resistivity not less than 30 Ω · m,
- chlorides not greater than 100 ppm, and
- Sulfates not greater than 200 ppm.

- ✓ Gradation Limits
- ✓ Direct Shear
- ✓ Plasticity
- ✓ Magnesium Sulfate Soundness
- ✓ Electrochemical Requirements
  - ✓ pH
  - ✓ Resistivity
  - ✓ Chlorides
  - ✓ Sulfates

Pullout Testing of Geogrids and Straps for MSE





PET & HDPE Geogrids **Steel & Poly Straps**

Images courtesy of SGI Lab, Atlanta, GA

Creep and Modulus

Creep

0.6% Strain from Day 1 to 50 years
For normal Stress up to ~5,000 psf

Elastic Modulus

522-730 tsf (50-70 MPa)
For normal Stress ~1,000-2,000 psf

Resilient Modulus

775-1,550 tsf (75-150 Mpa)
AASHTO T 307
Varies based on confining stress

Installation

- Maximum lift thicknesses of 24 inches (0.6 m)
- Compaction is performed with a tracked excavator or dozer 600 - 1,000 psf (30 - 50 kPa)
- 2 to 4 passes over the UL-FGA layer

Installation

Easily graded

Side Slopes @45˚

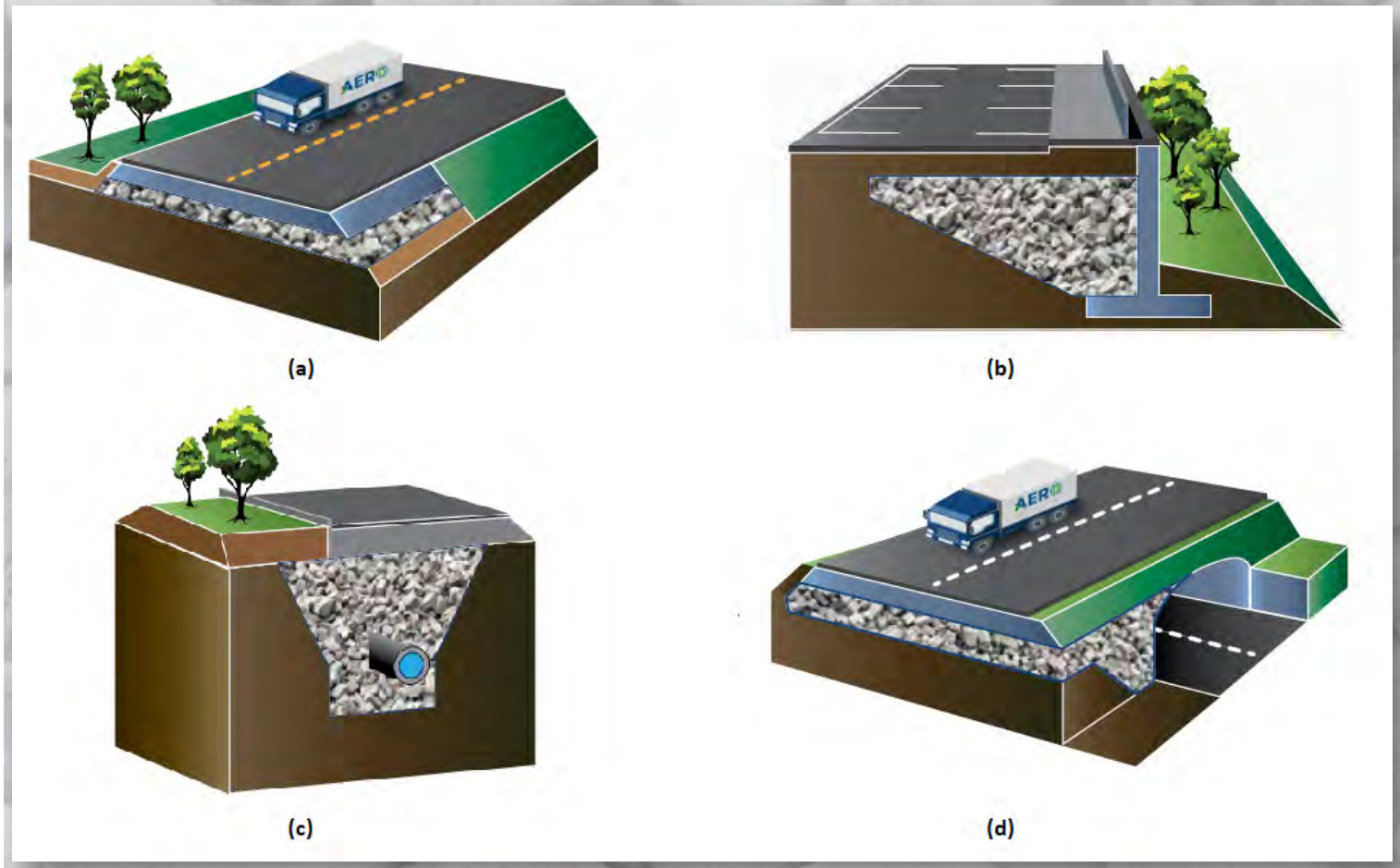
Geotextile Separator (6 oz/sy min.)

Shipping

- 100 CY Walking Trailer
  - (1) Load UL-FGA *--VS--*
  - (3) Loads other 'LW' Agg
  - (7.5) Loads Washed Stone
- Simplify Logistics in the Field
- Improve Efficiency in the Field
- *AND* Reduce Carbon Emissions

- Also, Delivers in Super Sacks
  - (3 CY) UL FGA = 1,200 Lbs *--VS--*
  - (3 CY) Stone = 8,500 Lbs

Applications …



Embankment over Soft Soils

Bridge Approaches

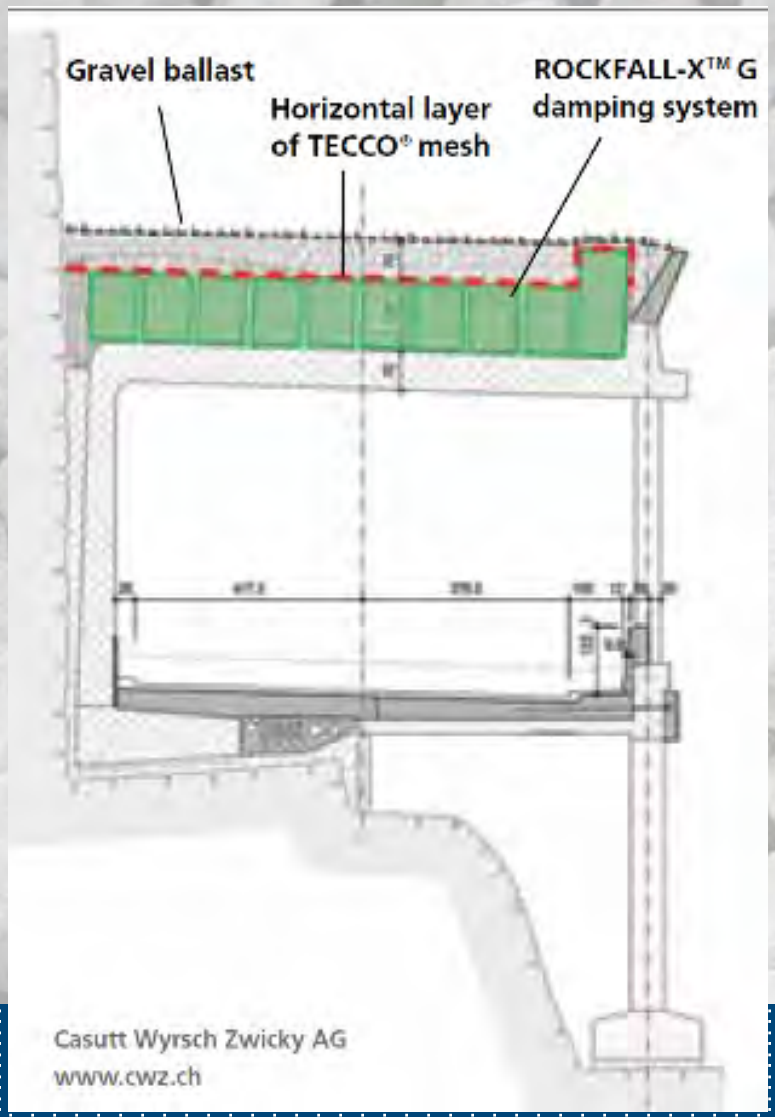
Cover over Tunnels, Culverts, Aging Utilities

Retaining Walls, Building Foundations, MSE Walls

Green Roofs, Under Foundation Slabs, Pipe Insulation, …

Applications …

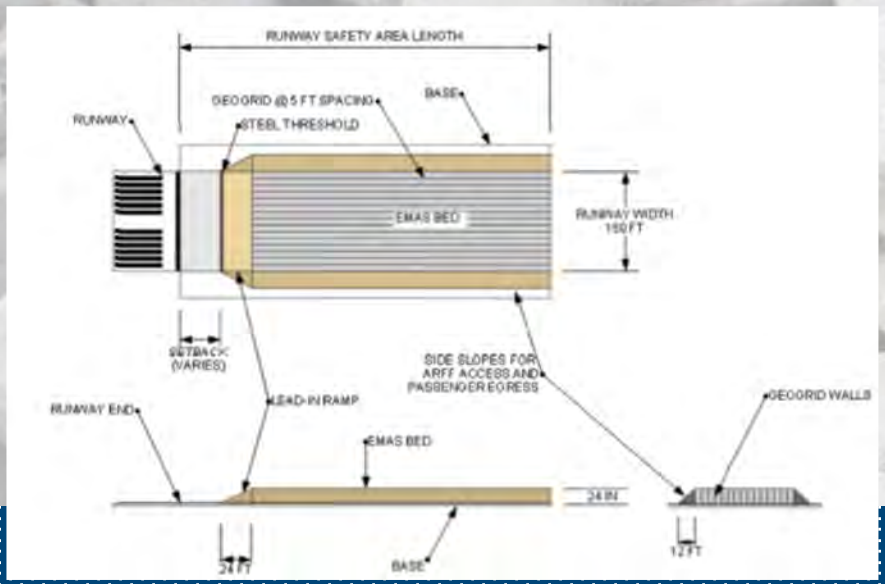
ROCKFALL PROTECTION



Images courtesy of Geobrugg AG ROCKFALL-X™ G

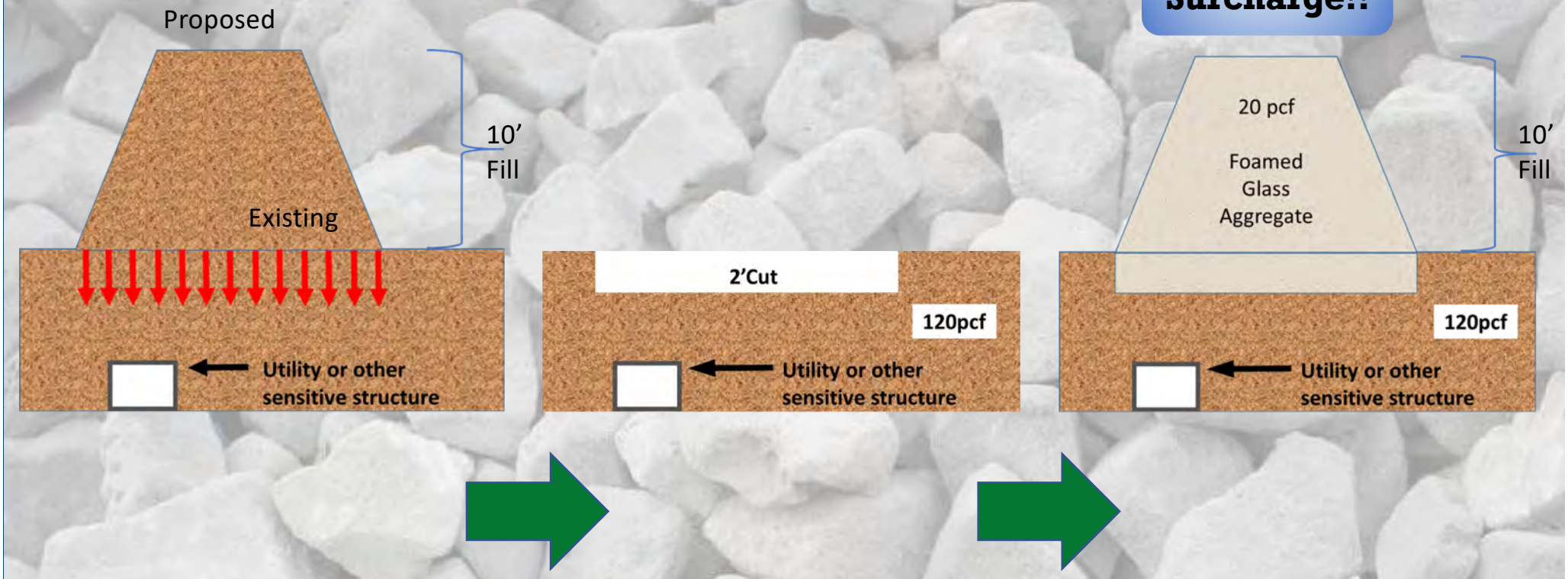
Applications …

EMAS



Images courtesy of Runway Safe

Soil Balancing



Reduced Carbon Footprint

- 50% Less CO_2 than Other Lightweight Materials
- 50% Less Energy Consumed than Other Lightweight Options

http://www.epd-norge.no/?lang=en_GB

epd-norge.no

An EPD® (Environmental Product Declaration) is an independently verified and registered document that communicates transparent and comparable information about the life-cycle environmental impact of products. Both the underlying LCA (Life-Cycle Assessment) and the EPD are always based upon international standards.

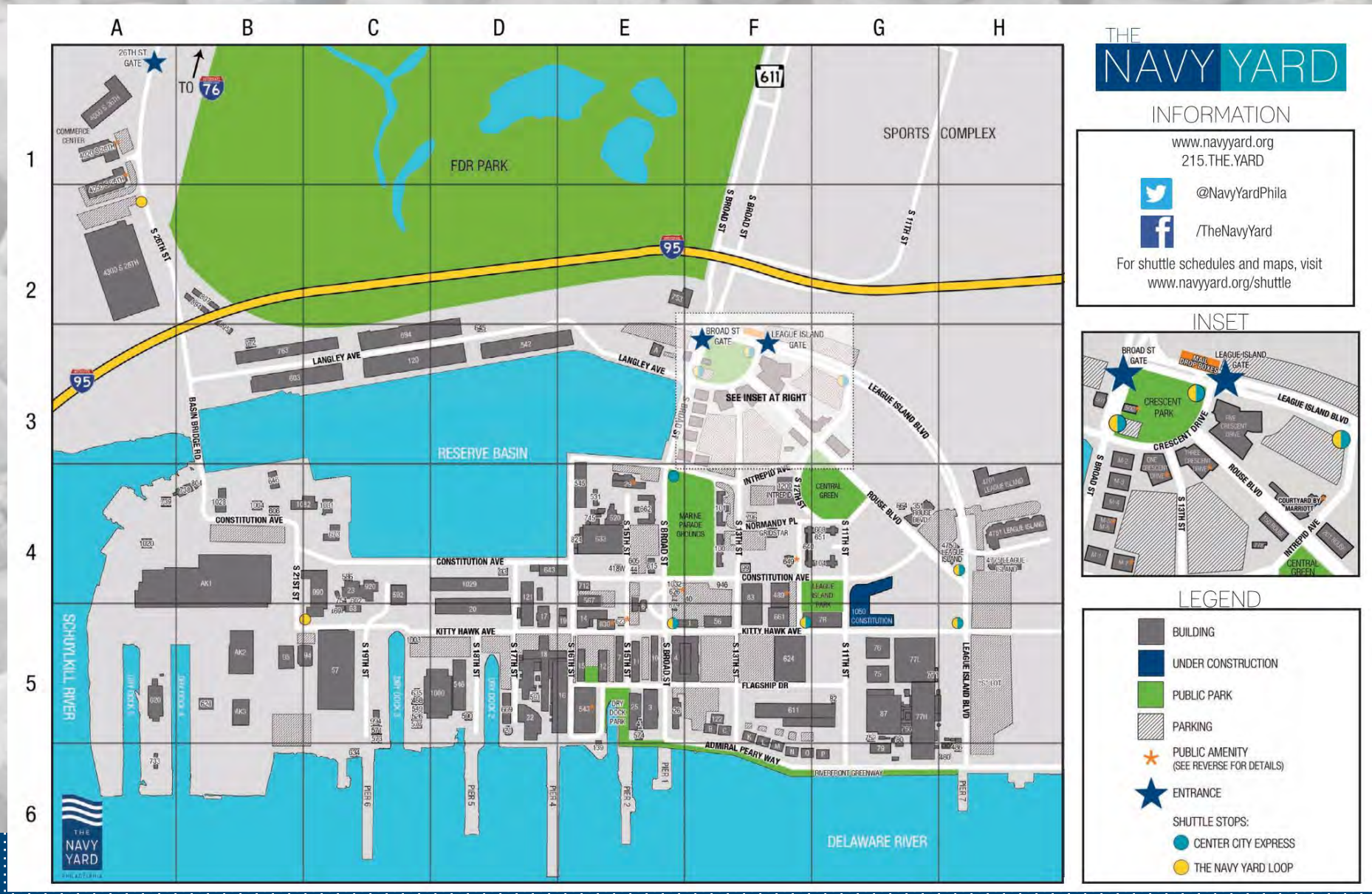
Regional Greenhouse Gas Initiative
an initiative of the Northeast and Mid-Atlantic States of the U.S.

PARIS CLIMATE CHANGE ACCORD

Case Studies

- Pennsylvania
  - Langley Avenue Navy Yard Access, Philadelphia
  - I-95 South, Philadelphia
  - JFK Blvd, Philadelphia
- New Jersey
  - RCA Pier, Camden
  - Wittpenn Bridge (Route 7), Kearny

Langley Avenue, Philadelphia



THE NAVY YARD

INFORMATION

www.navyyard.org
215.THE.YARD

@NavyYardPhila

/TheNavyYard

For shuttle schedules and maps, visit
www.navyyard.org/shuttle

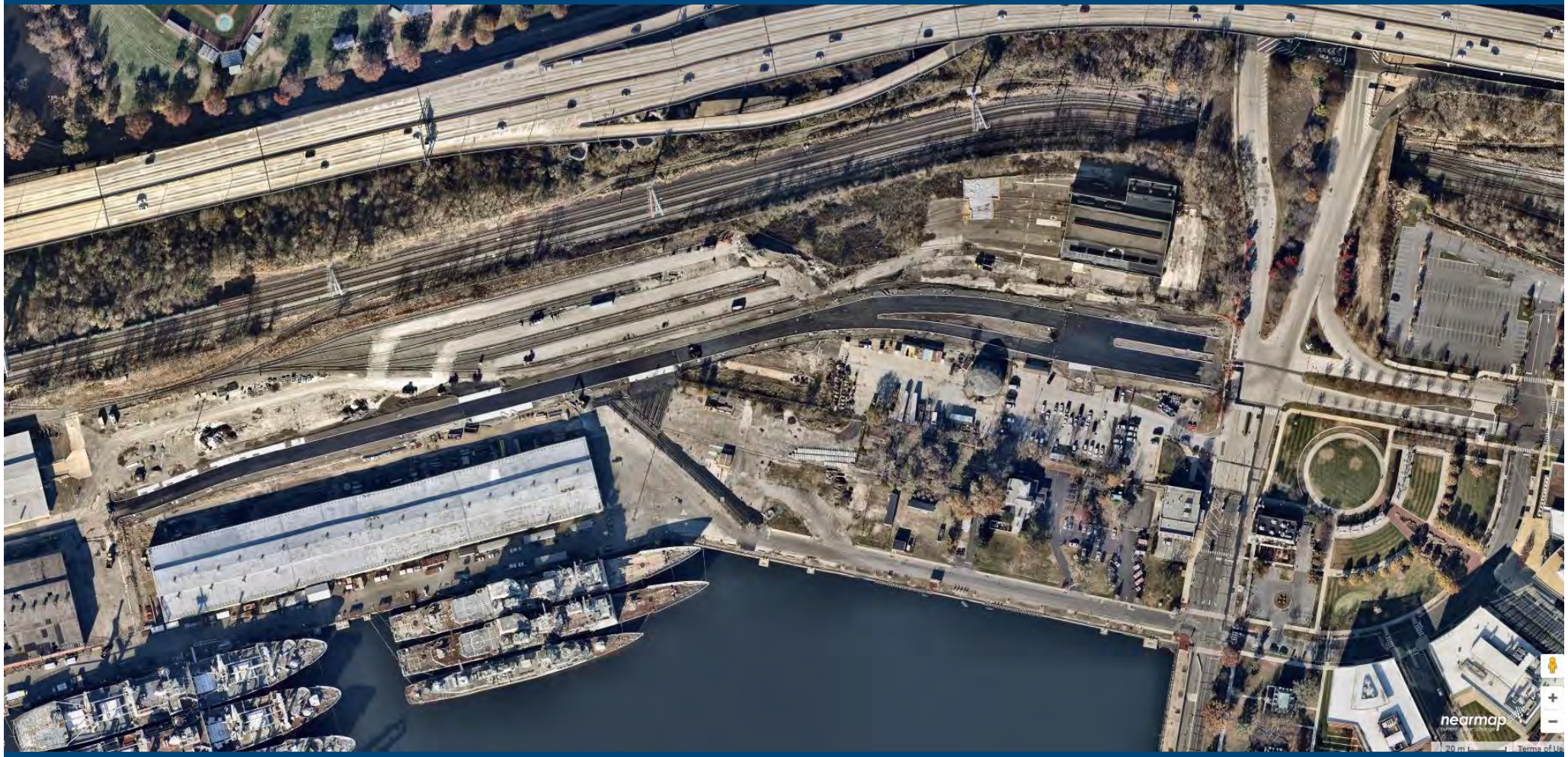
INSET

LEGEND

- BUILDING
- UNDER CONSTRUCTION
- PUBLIC PARK
- PARKING
- PUBLIC AMENITY (SEE REVERSE FOR DETAILS)
- ENTRANCE
- SHUTTLE STOPS:
  - CENTER CITY EXPRESS
  - THE NAVY YARD LOOP

PIDC Map
https://www.navyyard.org

Langley Avenue, Philadelphia



Nearmap Aerial – 1/23/2017
https://go.nearmap.com/

Langley Avenue, Philadelphia

Nearmap Aerial – 1/23/2017
https://go.nearmap.com/

Langley Avenue, Philadelphia

PIDC
Driving growth to every corner of Philadelphia

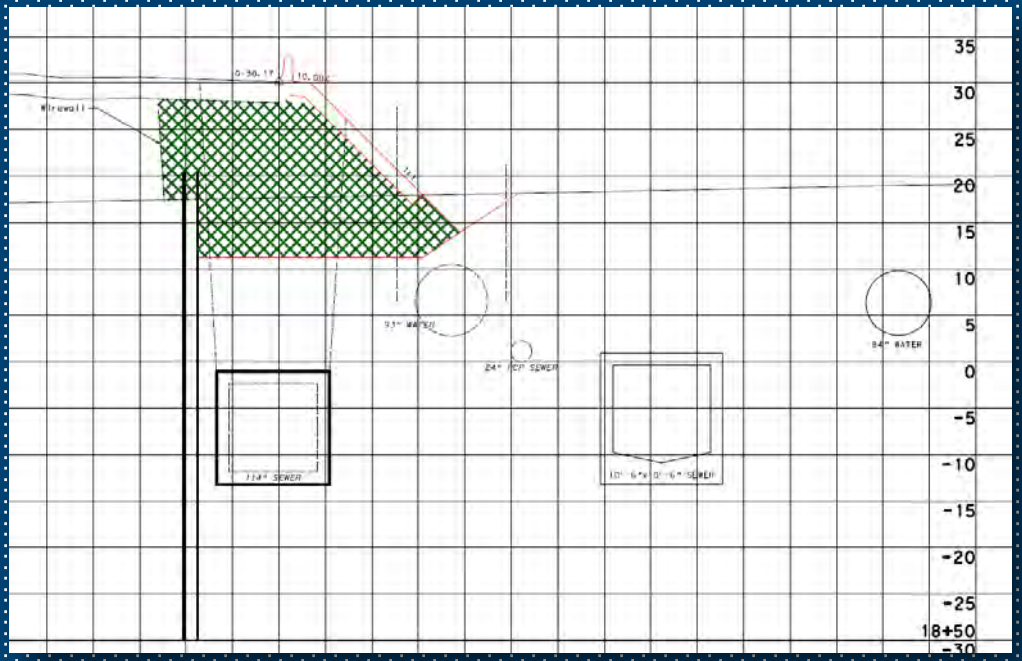
THE NAVY YARD
PHILADELPHIA

Langley Avenue, Philadelphia

PIDC
Driving growth to every corner of Philadelphia

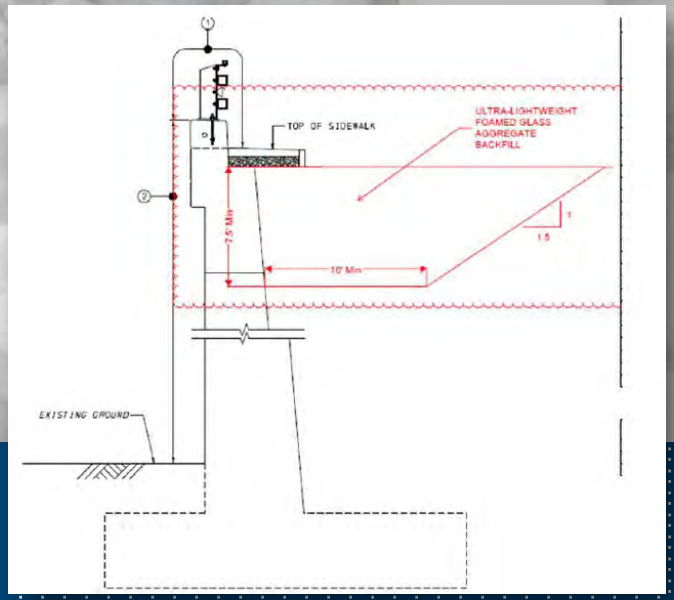
THE NAVY YARD
PHILADELPHIA

I-95 South, Philadelphia



I-95 South, Philadelphia

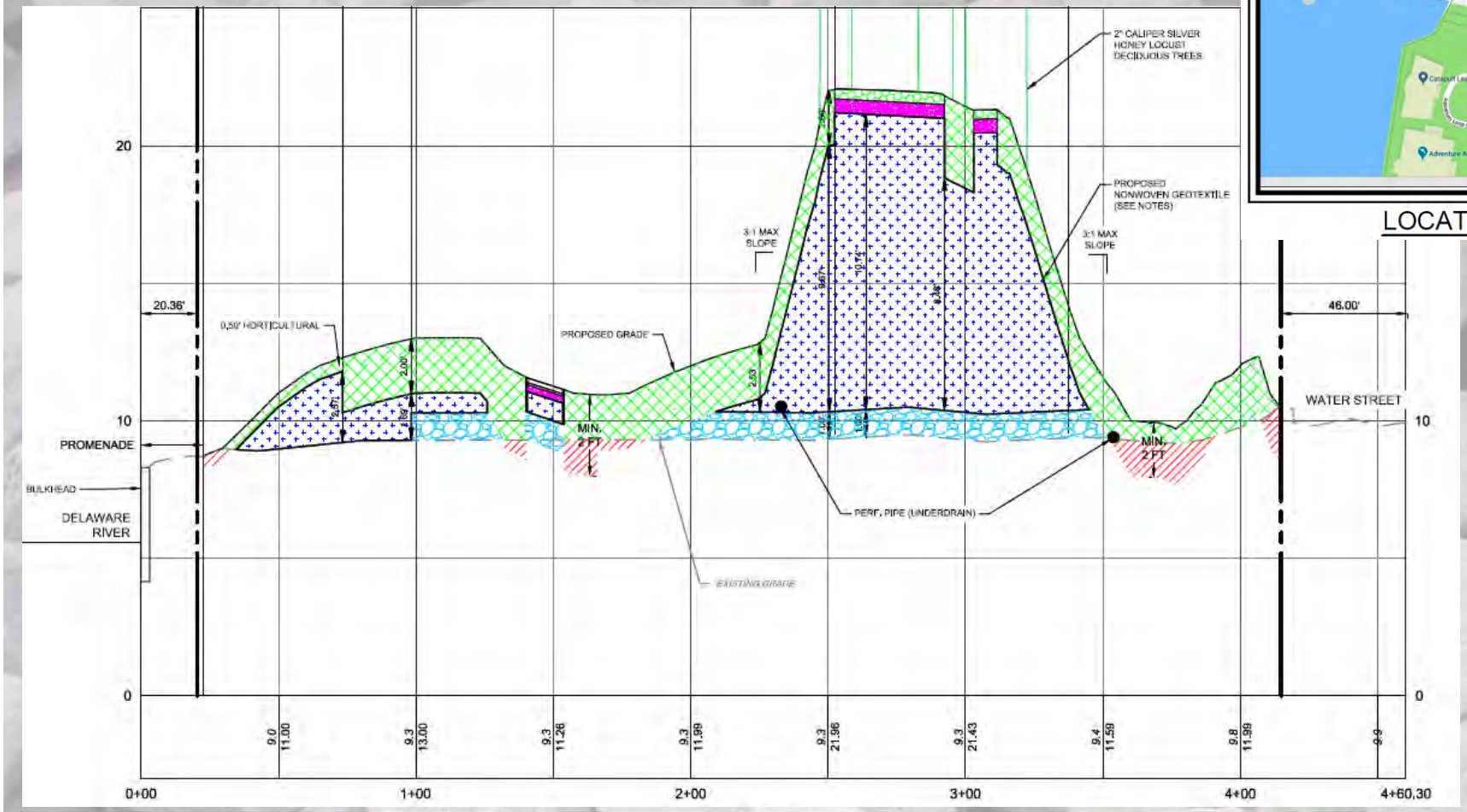
JFK Blvd, Philadelphia



JFK Blvd, Philadelphia

RCA Pier, Camden

LOCATION MAP



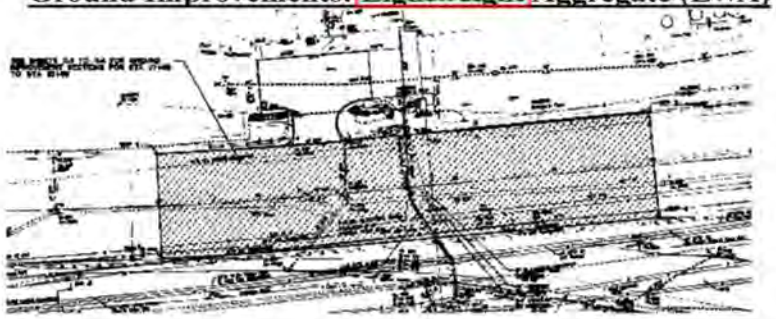
Pennoni

RCA Pier, Camden

Wittpenn Bridge, Kearny

RT 7 Hackensack River Wittpenn Bridge Contract 4

Ground Improvements: Lightweight Aggregate (LWA)

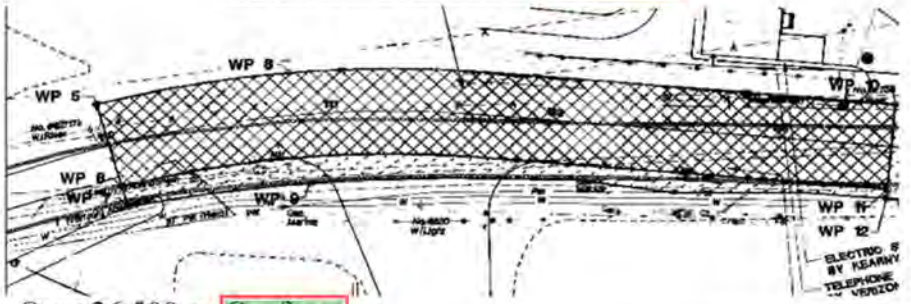


- 38,500 cy LWA
- Use Geotextile at base of LWA
- Over-excavation required prior to placing LWA
- Dewatering required during earthwork

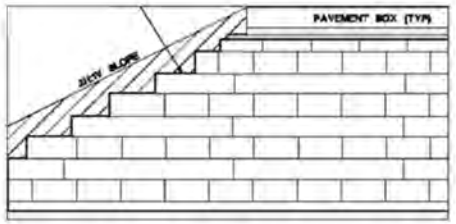
wittpenn

RT 7 Hackensack River Wittpenn Bridge Contract 4

Ground Improvements: Geofoam



- Over 26,500 cy Geofoam
- Wrapped in Geomembrane
- Covered with 4" concrete slab
- Staged Construction Required along FHR Sta 130 to 133+50 to maintain traffic



wittpenn

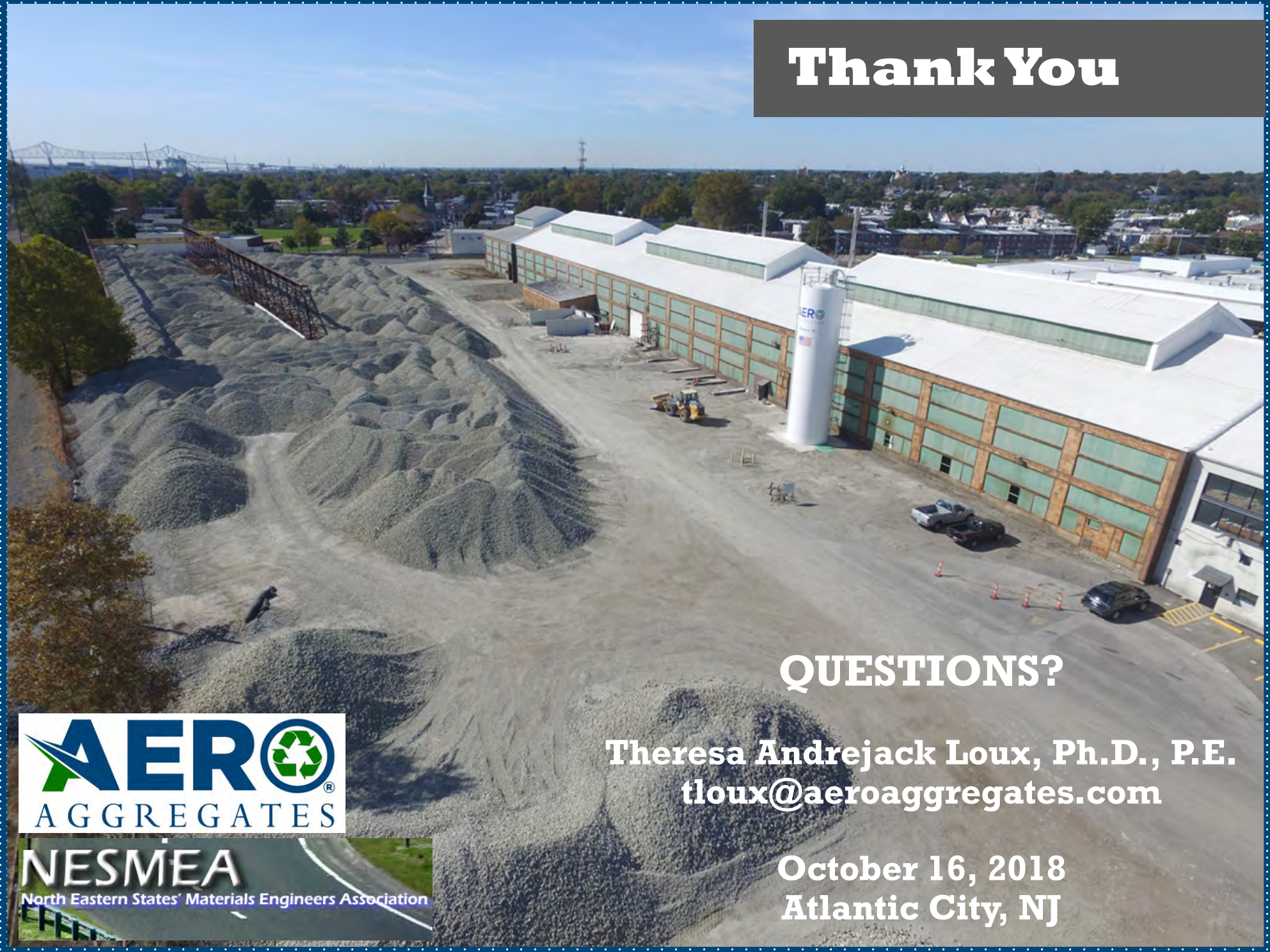
Wittpenn Bridge, Kearny

Wittpenn Bridge, Kearny

Foamed Glass Aggregate

- Ultra Lightweight Engineered Material
- High Strength to Density Ratio
- High Friction Angle, MSE Wall Tested
- Durable
- Chemically, UV, Volume Stable
- Efficient Installation, Not Weather Sensitive
- Sustainable and Environmentally Responsible

Thank You



QUESTIONS?

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tloux@aeroaggregates.com

October 16, 2018
Atlantic City, NJ

AERO AGGREGATES

NESMEA
North Eastern States' Materials Engineers Association