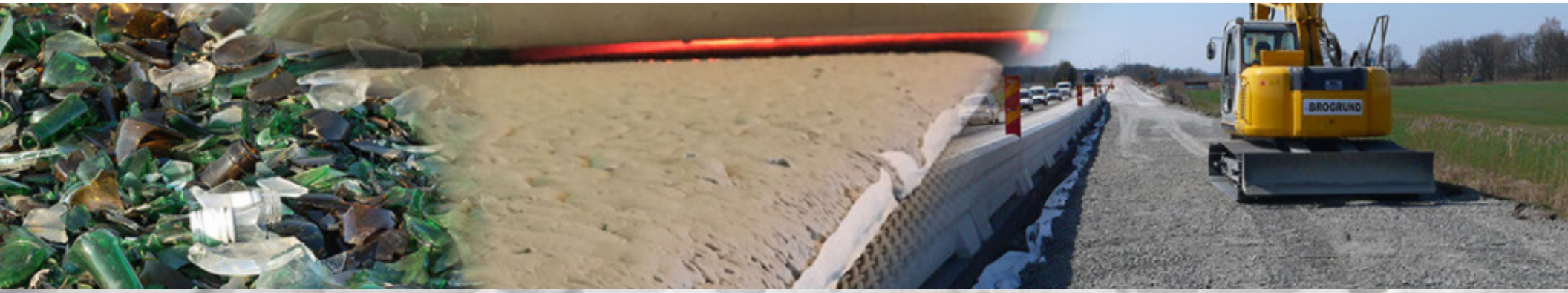


FOAMED GLASS AGGREGATE:
A "New" and Unique Lightweight Fill

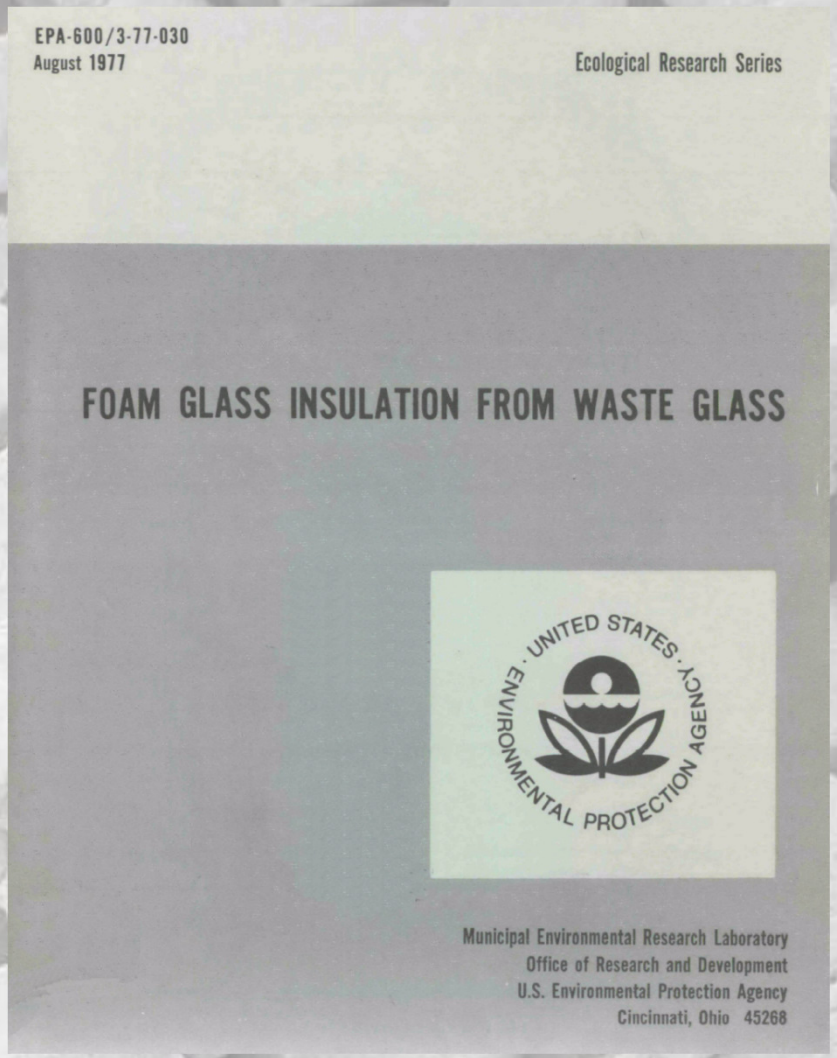
Mid-Atlantic QAW
February 14, 2018

Outline

- Introduction
- History of Development
- Material Properties
- Applications and Installation
- Research and Testing
- Case Studies

Introduction

History
US EPA - Insulation
1977

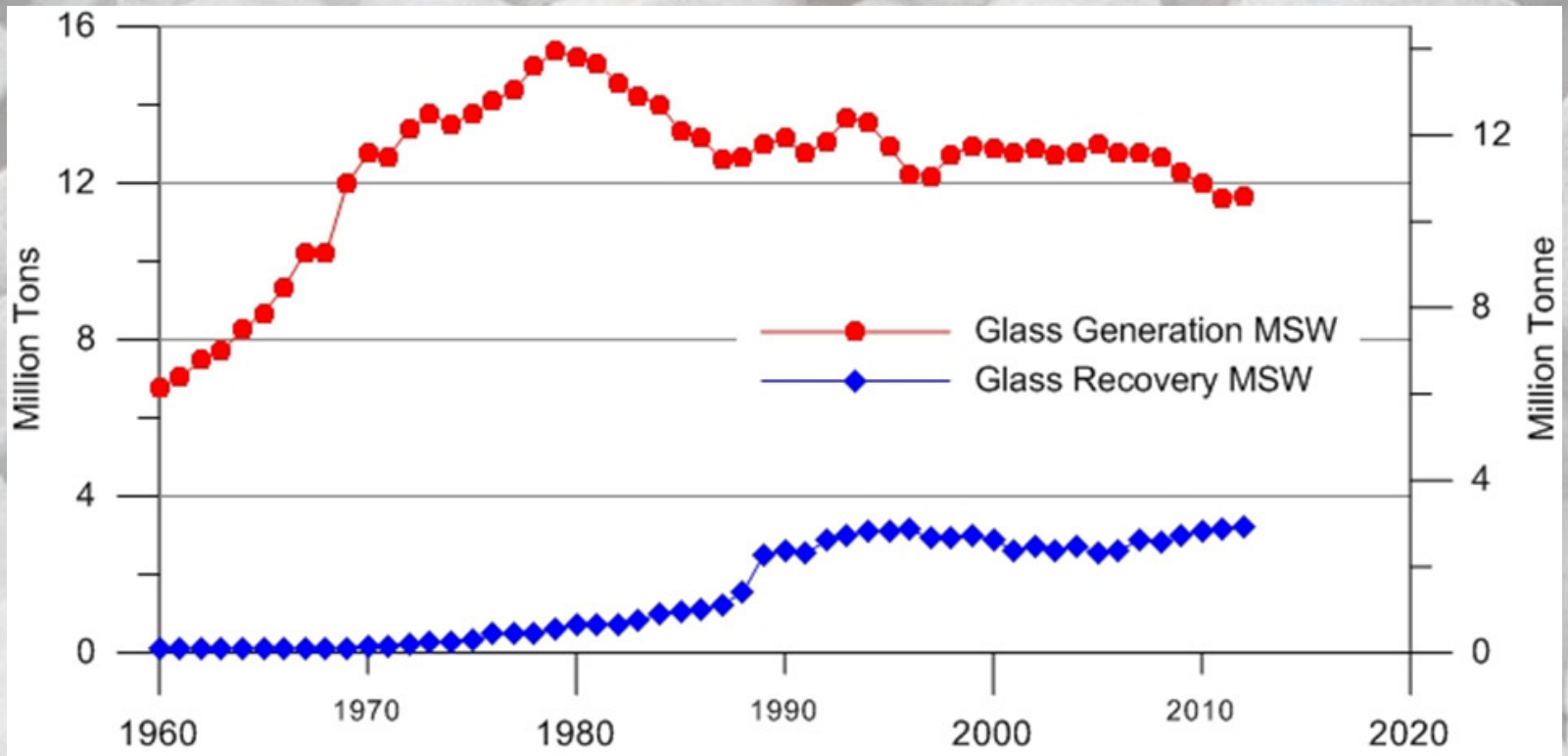


History of Foamed Glass Aggregates - Europe

- Developed in Germany in early 1980s
- Technology taken to Norway in 1990s
- Thermal barrier for roadways
- Led to lightweight applications
- Growth throughout Scandinavia
  - Geotechnical Applications
- Germany and Switzerland
  - Thermal insulation
  - Additive for lightweight concrete

Glass Containers: 9.38 M tons/year Recovery ~34%

Total Glass: 11.57 M tons/year Recovery ~28%



US EPA

Glass Processing

MRF-Cleaning-Milling

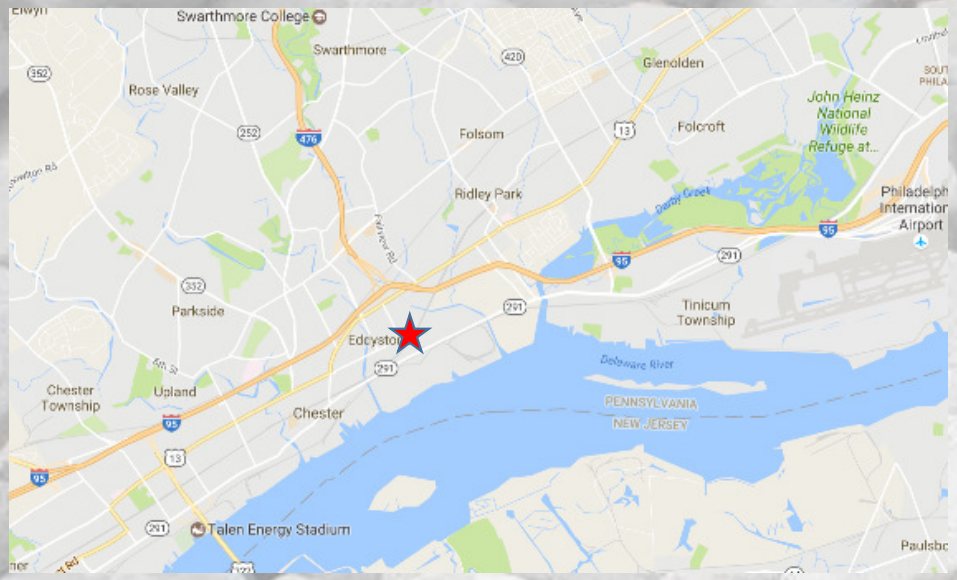
- Cleaning of glass cullet
- Uses all colors and any size

- Milled into powder
- Mixed with foaming agent

Process transforms the cullet into a new material

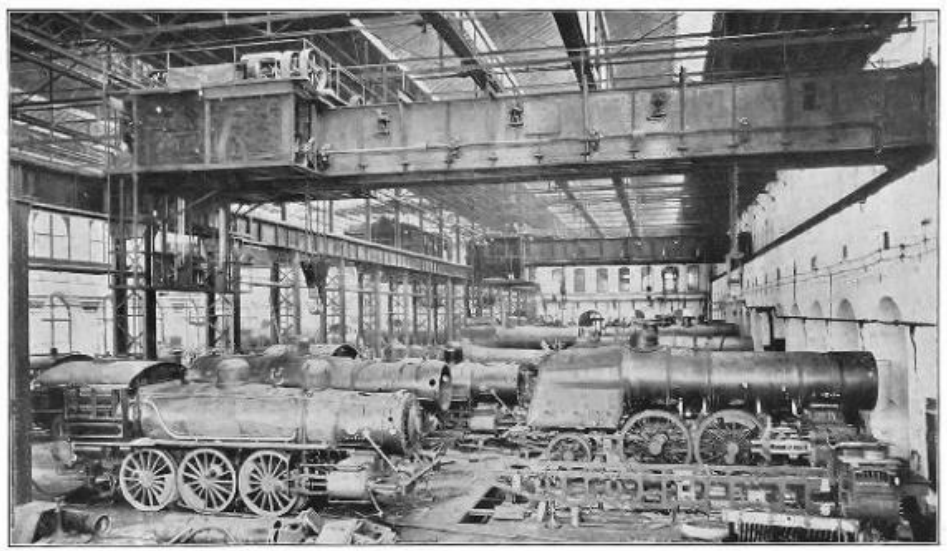
AERO AGGREGATES

1500 Chester Pike, Eddystone, PA



10 acre site

Baldwin Locomotive Plant



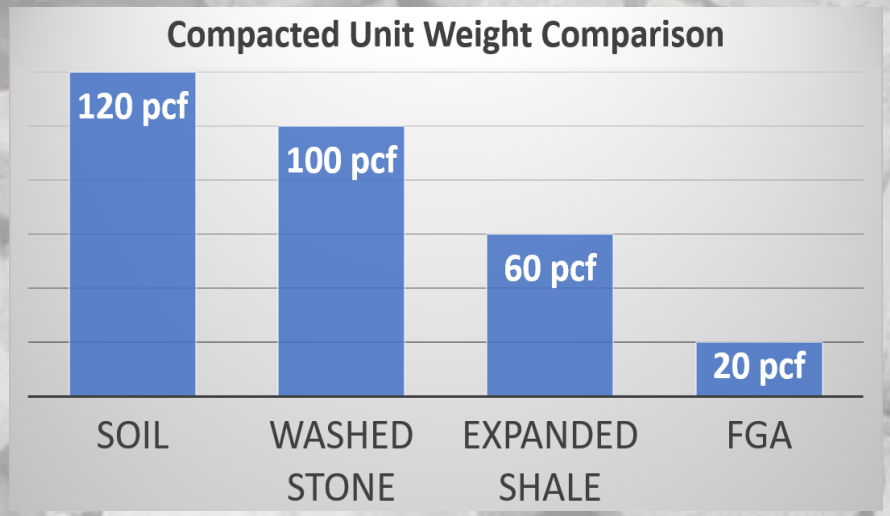
97,000 sq.ft. building

Baldwin Facility

UL-FGA

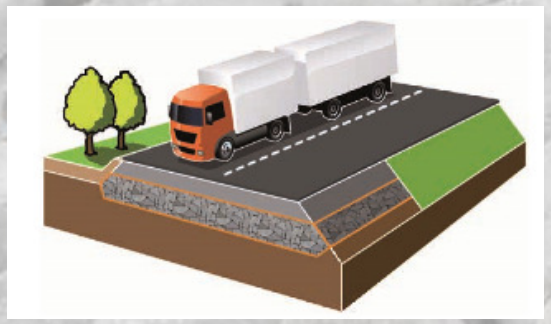
ULTRA-LIGHTWEIGHT
FOAMED GLASS AGGREGATES

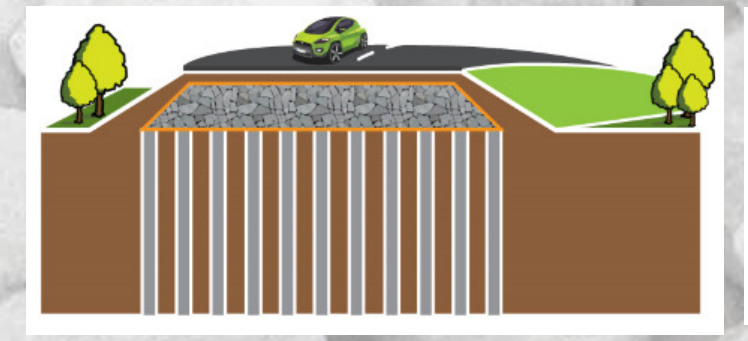
Property	Units	Value
Particle Size	mm (in)	10 – 60 (0.4 – 2.4)
Loose Bulk Density (dry), max	kg/m³ (pcf)	240 (15)
Compacted Density (dry)	kg/m³ (pcf)	265-310 (16.5-19.5)
Thermal Conductivity	W/mK	0.11 dry 0.15 wet
Peak Friction Angle	degrees	55.7

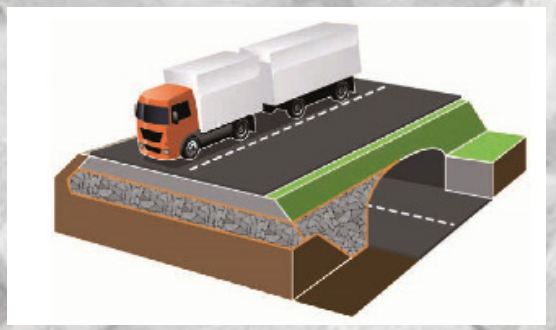


Applications

- Many uses for lightweight aggregates
  - Embankment fill over soft soils
  - Retaining walls
  - Bridge abutments
  - Reduced lateral load of backfill
  - Lightweight fill over culverts and utilities
  - Under foundation slab insulation and drainage
  - Insulation layer
    - Horizontal or vertical
  - Greenroofs







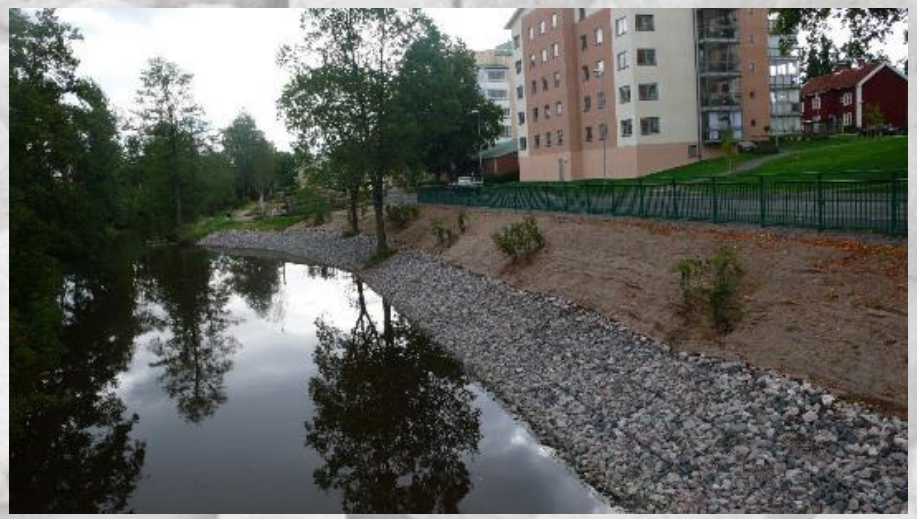
Transportation

Highway Embankments and Landslide Repairs

Norwegian Public Road Authority

Transportation

Highway Embankments and Landslide Repairs



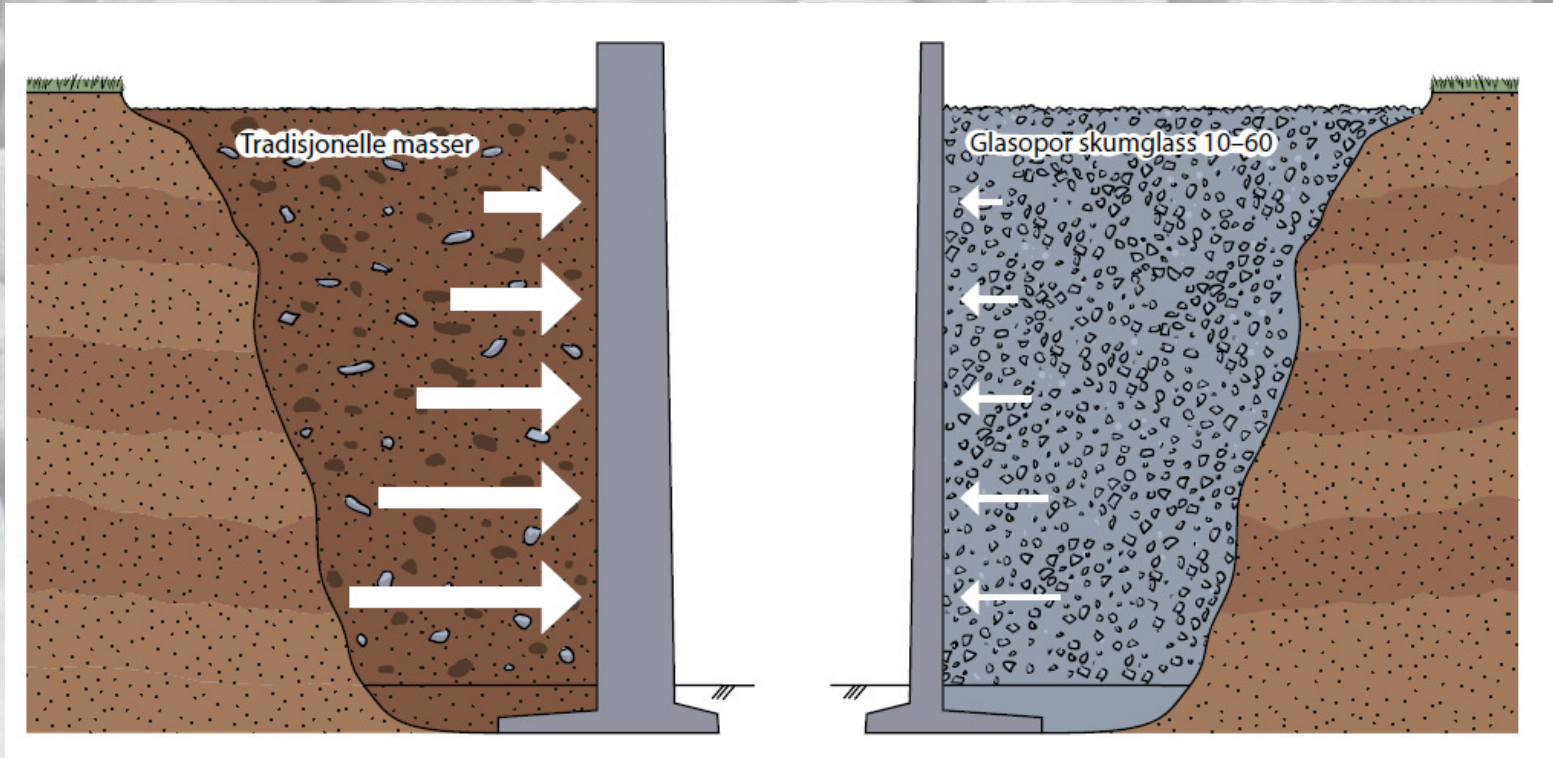
Hasapor Sweden

Approach Fill for Bridge Abutments

Hasopor, Sweden

- Reduces lateral earth pressure
- Reduces settlement at interface

Lightweight Backfill for Retaining Walls



Glasopor, Norway

Lightweight Backfill against Foundations

Uusioaines Oy, Finland

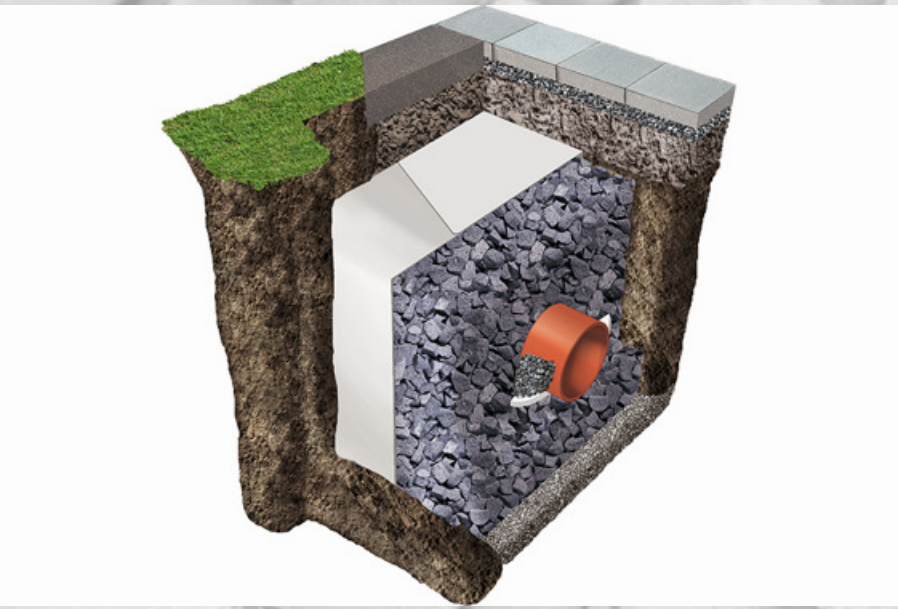
Cut and Cover Tunnels

Insulation for Permafrost

Drainage and Capillary Break

Norwegian Public Road Authority

Insulation and Lightweight Backfill - Utilities

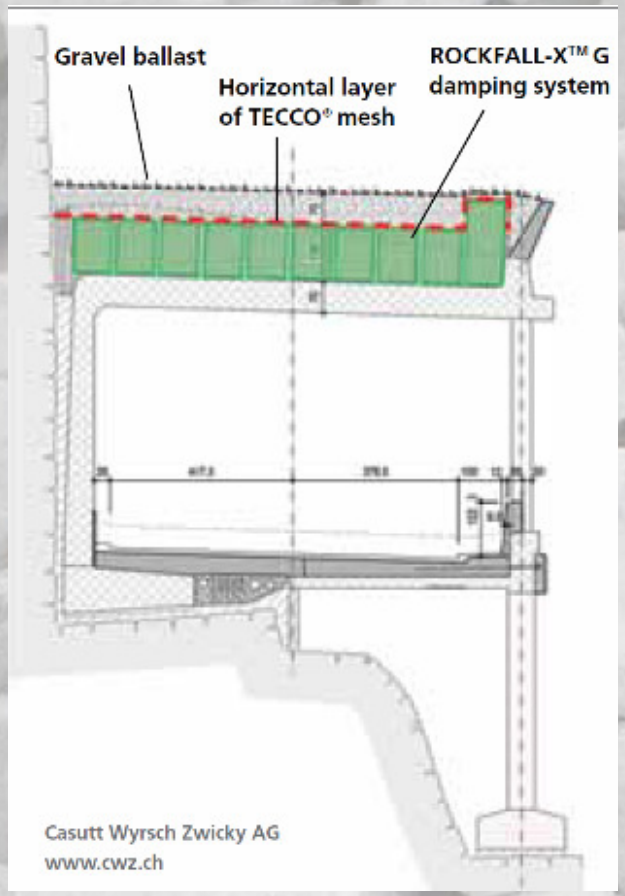


Sound Walls

SGGC Germany

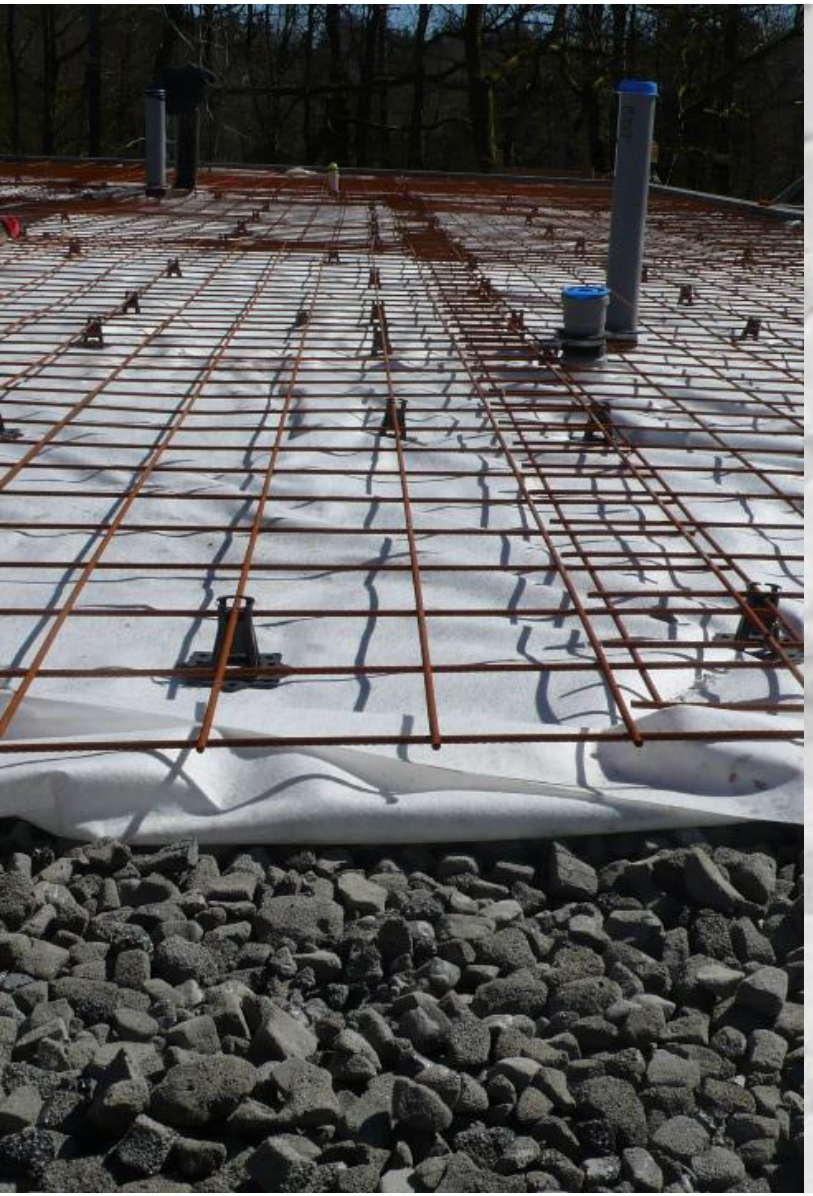
- Absorbs noise
- Lightweight – reduced foundation
- Porous
- UV Stable

Rockfall Protection



Geobrugg AG ROCKFALL-X™ G

Green Roofs



Under Slab

- Insulation
- Bearing capacity
- Drainage
- Capillary Break

Under Foundations

Meets European Energy Efficiency Requirements

Lightweight Additive for Concrete

Misapor

Installation and Compaction

- 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 and Compaction

Easily graded

Plate Compactor Lifts 12” Max.

Side Slopes @ 45˚

- Geotextile Separator (Recommended 6 oz./SY minimum)
- Cover soil

Shipping

- Up to 100 CY/trailer
- Reduced carbon footprint
  - 1 trailer of Foamed Glass
  - 7 tri-axial loads of stone

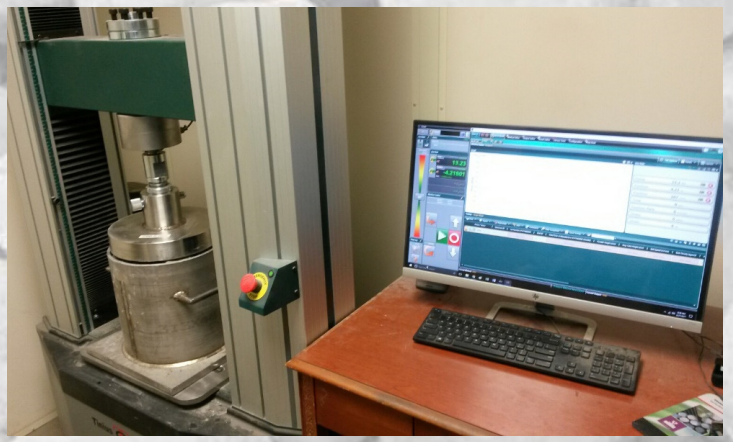
Delivery in Super Sacks
3CY 1,200 lbs. vs. 8,000 lbs.


Research and Testing

Quality Control Program

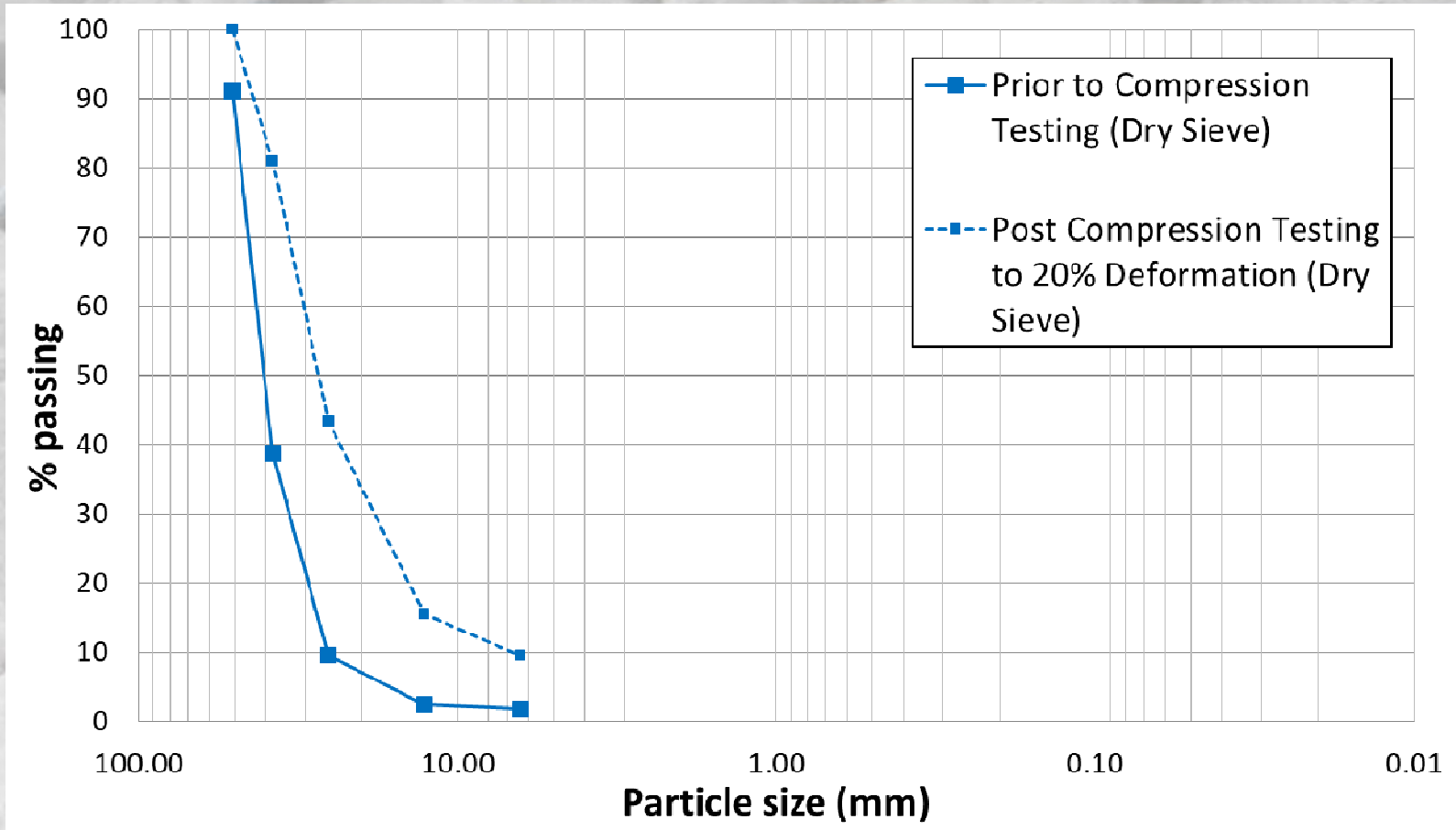
- Modified versions of the European Standard EN 1097-11, “Tests for mechanical and physical properties of aggregates, Part 11: Determination of compressibility and confined compressive strength of lightweight aggregates”.
  - Density (Dry, bulk density < 15 pcf)
  - Compression (Stress @ 20% Deformation > 15,000 psf)

Determination of dry bulk density



Compressive Strength Testing

GSD Pre- and Post-Compression Testing

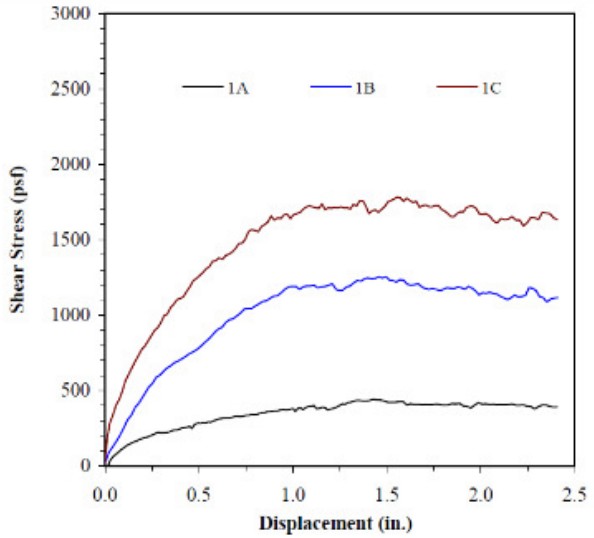


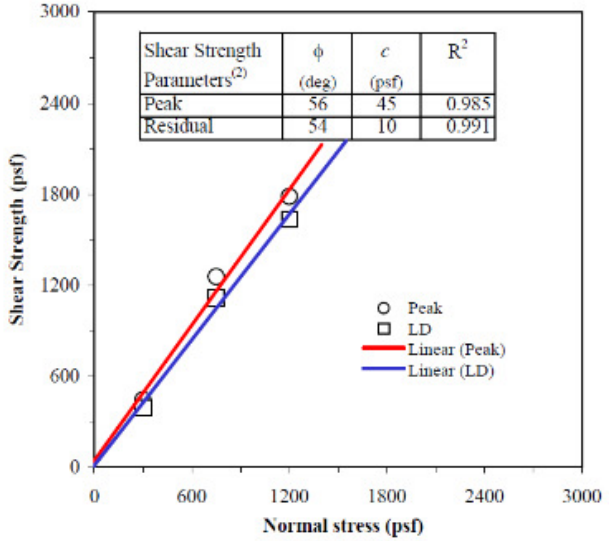
Source: AeroAggregates

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		Consolidation						Soil Compaction			Shear Strength		Failure Mode
						Step 1		Step 2		Step 3							
				(psf)	(hour)	(psf)	(hour)	(psf)	(hour)	(psf)	(hour)	γ_m (pcf)	ω_i (%)	ω_f (%)	τ_P (psf)	τ_R (psf)	
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.

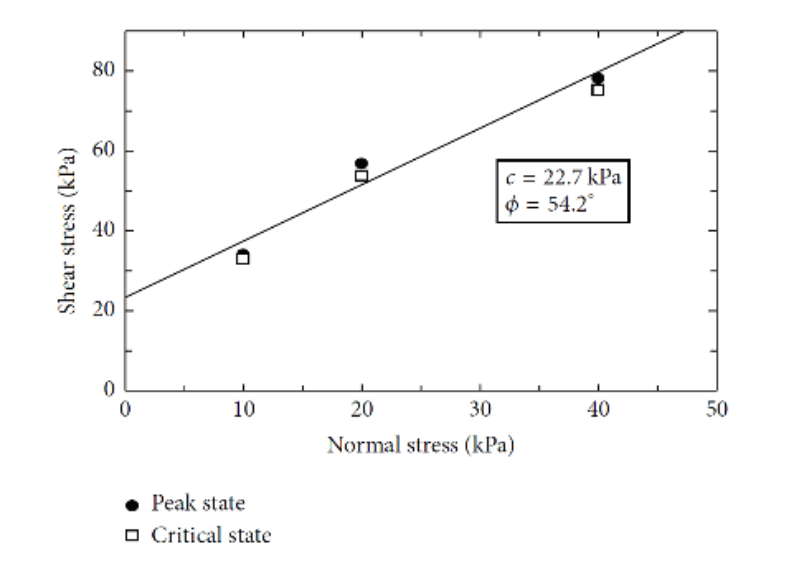
(2) The reported total-stress parameters of friction angle and cohesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The residual shear strength was calculated using the shear force measured at the end of the test.

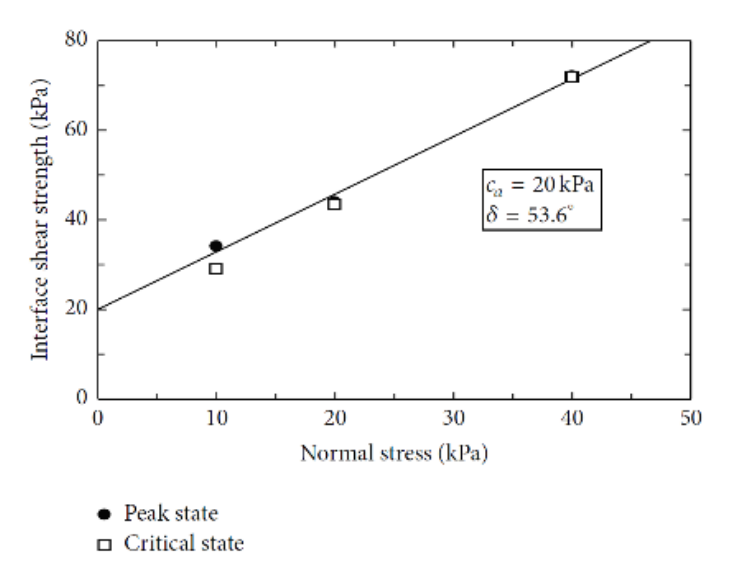
DATE REPORTED:	4/28/2016
FIGURE NO.	C-1
PROJECT NO.	SGI16023
DOCUMENT NO.	
FILE NO.	

SGI TESTING SERVICES, LLC

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*.

- Evaluation of Interface Shear Strength
- Geogrid/FG interface shear strength





Moisture Content and Buoyancy

Moisture Content

- Adsorption of Water to Surface – for 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)

Retaining Walls

- T-Wall – The Neel Company
- RECO – FGA meets the backfill requirements for steel straps

- Pullout Testing completed for PET and HDPE Geogrids
- Pullout Testing completed on steel and Poly straps


European Case Studies

New Metro Line

From Jar to Kolsås

- Constructed over marsh area
- Owner wanted to reduce excavation
- From top-bottom:
  - Tracks
  - Ballast
  - Subbase
  - GT
  - FGA
  - GT
  - Subbase
  - GT

Halden Rail Yard

- Expansion of Rail yard
- 6 new tracks
- Very soft soil near river
- Required lightweight option to reduce surcharge
- 15,000 m^3 used to build up area

New E18 Motorway - Retvet- Knapstad

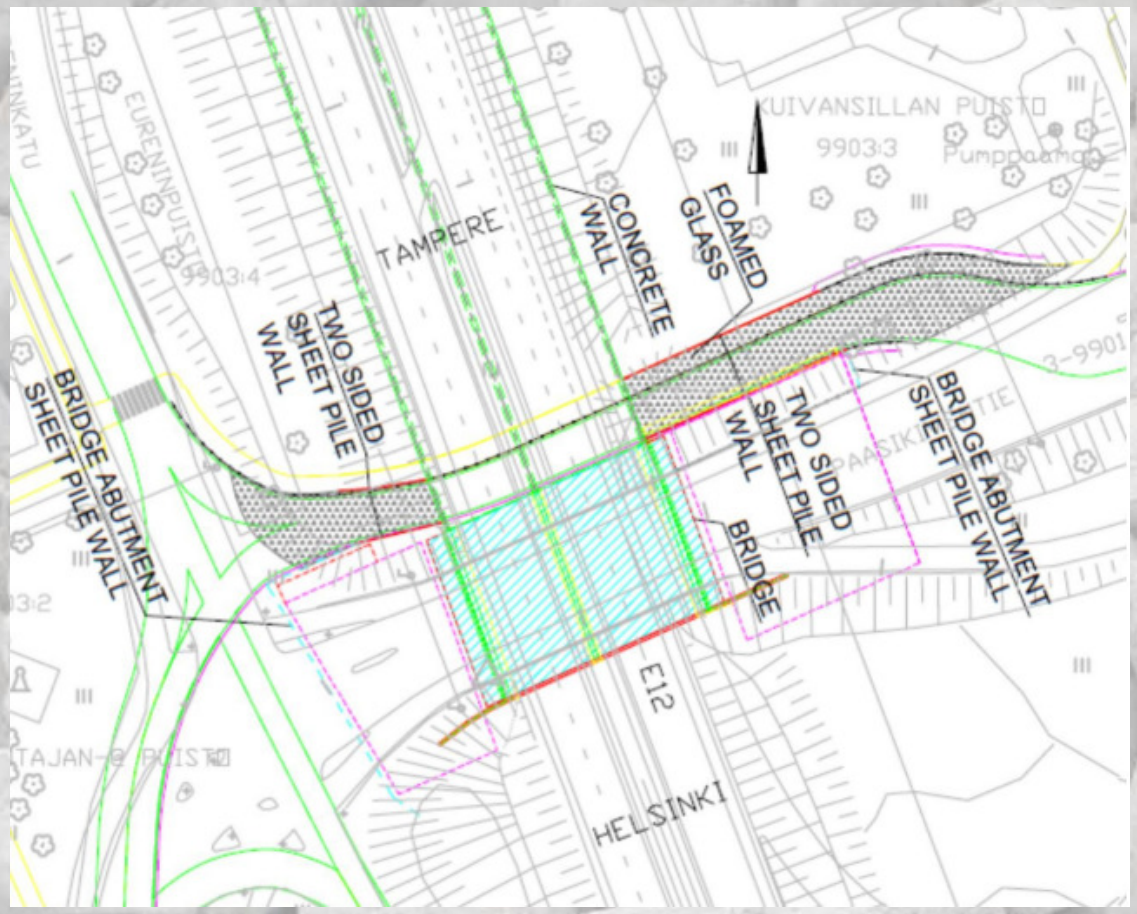
- 61,000 m^3 FGA is part of the new E18 Winton - Vinterbro.
- The six-kilometer long stretch to be built 20 meters wide
- Motorway with four lanes and central reserve.
- The stretch will have a speed limit of 100 km / h.

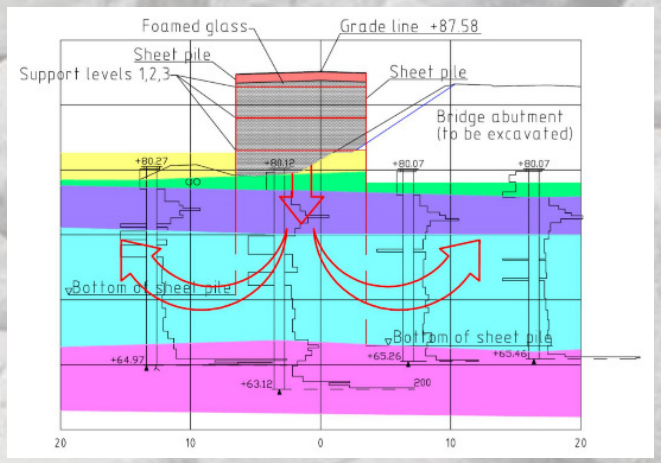
Norwegian Public Roads Administration

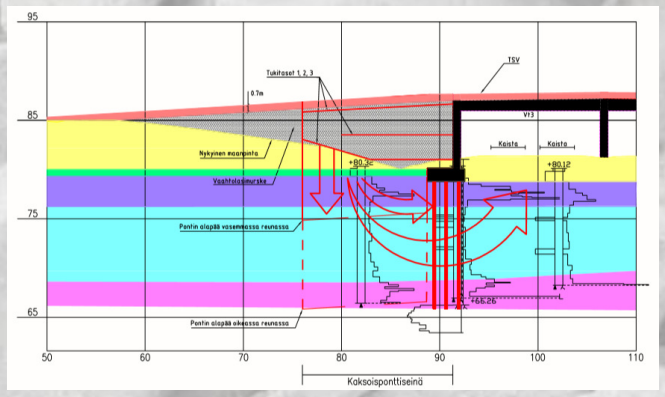
Sørenga Bridge Approach

- Reconstruction of Bridge approaches due to settlement
- Total of 4,000 m^3

Hämeenlinna, Highway E12







Hämeenlinna, Highway E12

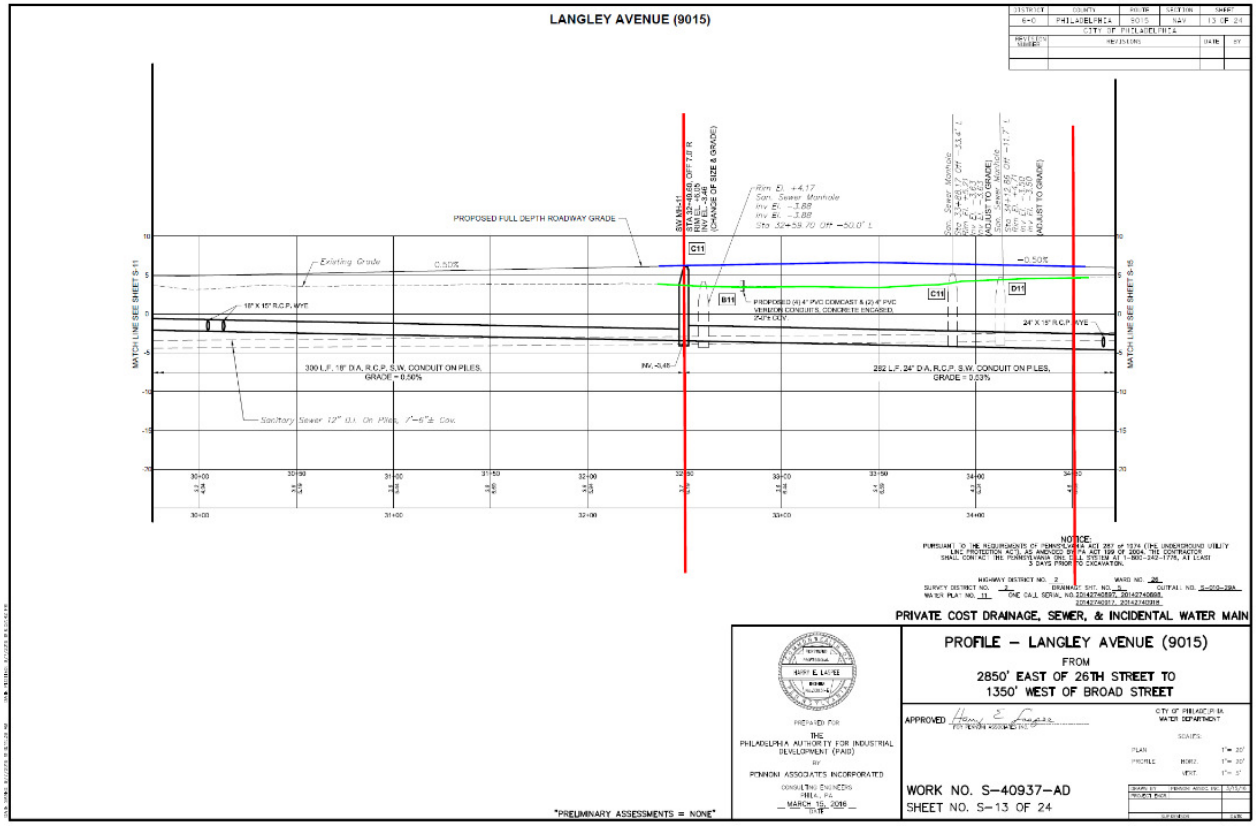
Hämeenlinna, Highway E12

Current DOT status

- Approved by MD SHA
- Approved VDOT
- 2 Projects with PADOT
- 1st Project with NJDOT
- NYSDOT
- MassDOT
  - READi (Review, Evaluate, Accelerate, Deploy, innovation) Committee
- ConnDOT
- NHDOT
- PA Turnpike – Innovation Council in October 2017


U.S. Case Studies

Philadelphia Navy Yard - PADOT



Philly Navy Yard -- PADOT

PIDC
Driving growth to every corner of Philadelphia

THE NAVY YARD
PHILADELPHIA

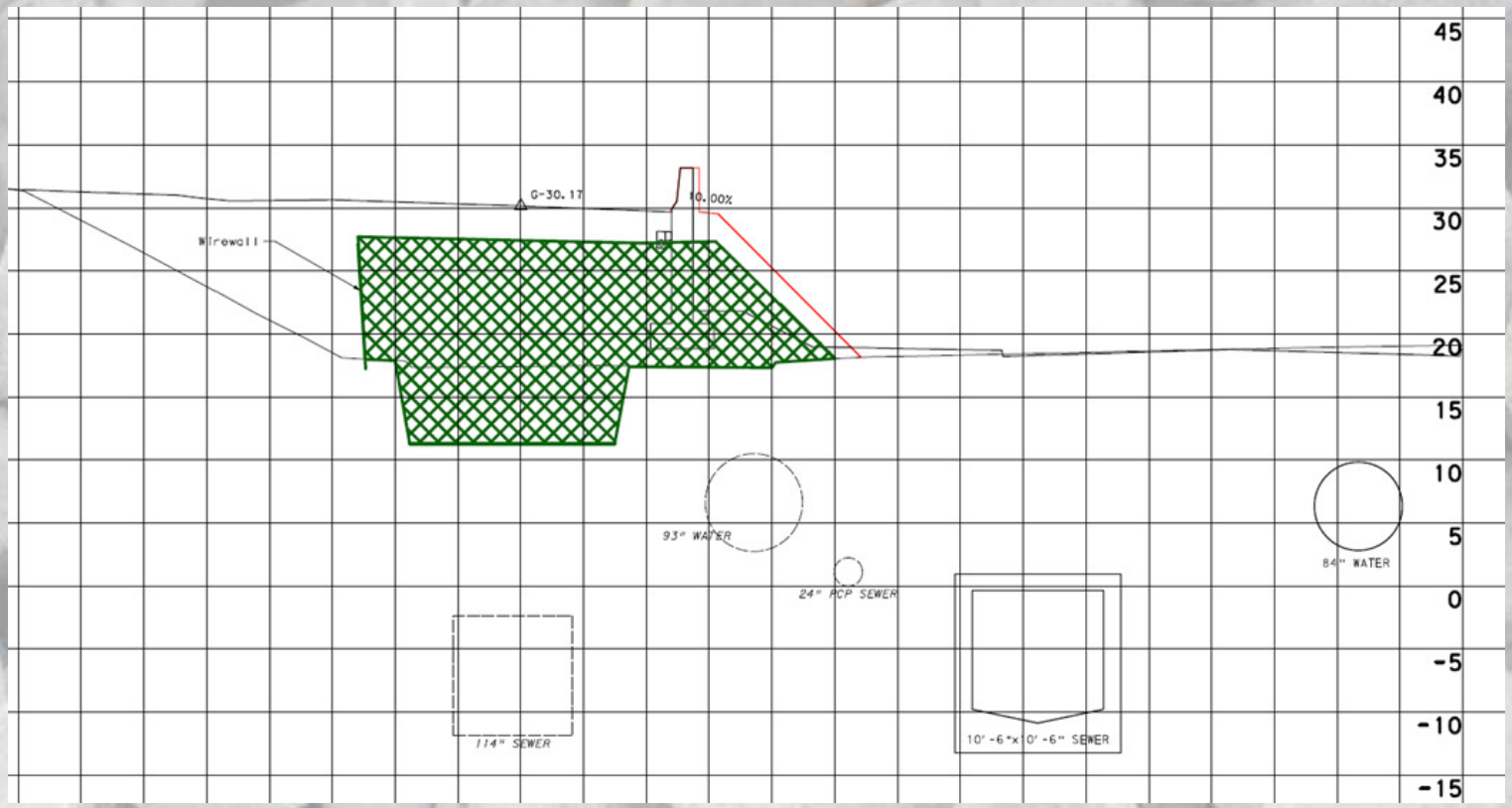
PA DEP Press Release 11/27 – **"First North American Use"**
– **"Its reuse right here in the city"** **Secretary Patrick McDonnell**

http://www.ahs.dep.pa.gov/NewsRoomPublic/articleviewer.aspx?id=21344&typeid=1

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

Pennsylvania
Recycling Markets Center
The Keystone of Recycling Markets Development

I-95 - CP2 - Ramp F -- PADOT

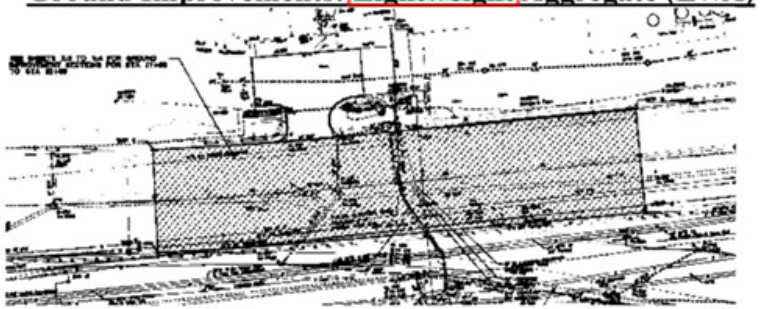


The Lightest Aggregate Available – The Benefit of being Ultra-Lightweight

Route 7 / Hackensack -- NJDOT

RT 7 Hackensack River Wittpenn Bridge Contract 4

Ground Improvements: Lightweight Aggregate (LWA)

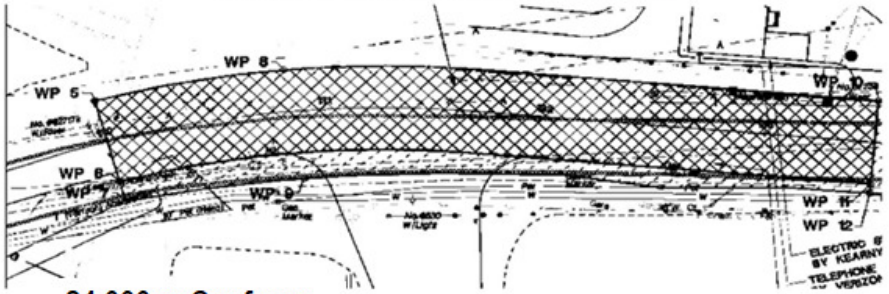


- ~28,000cy LWA
- Use Geotextile at base of LWA
- Over-excavation required prior to placing LWA
- Dewatering required during earthwork

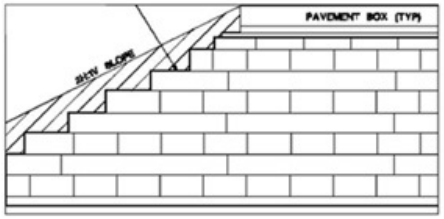
wittpenn BRIDGE REPLACEMENT

RT 7 Hackensack River Wittpenn Bridge Contract 4

Ground Improvements: Geofoam



- ~24,000cy Geofoam
- Wrapped in Geomembrane
- Covered with 4" concrete slab
- Staged Construction Required along FHR Sta 130 to 133+50 to maintain traffic



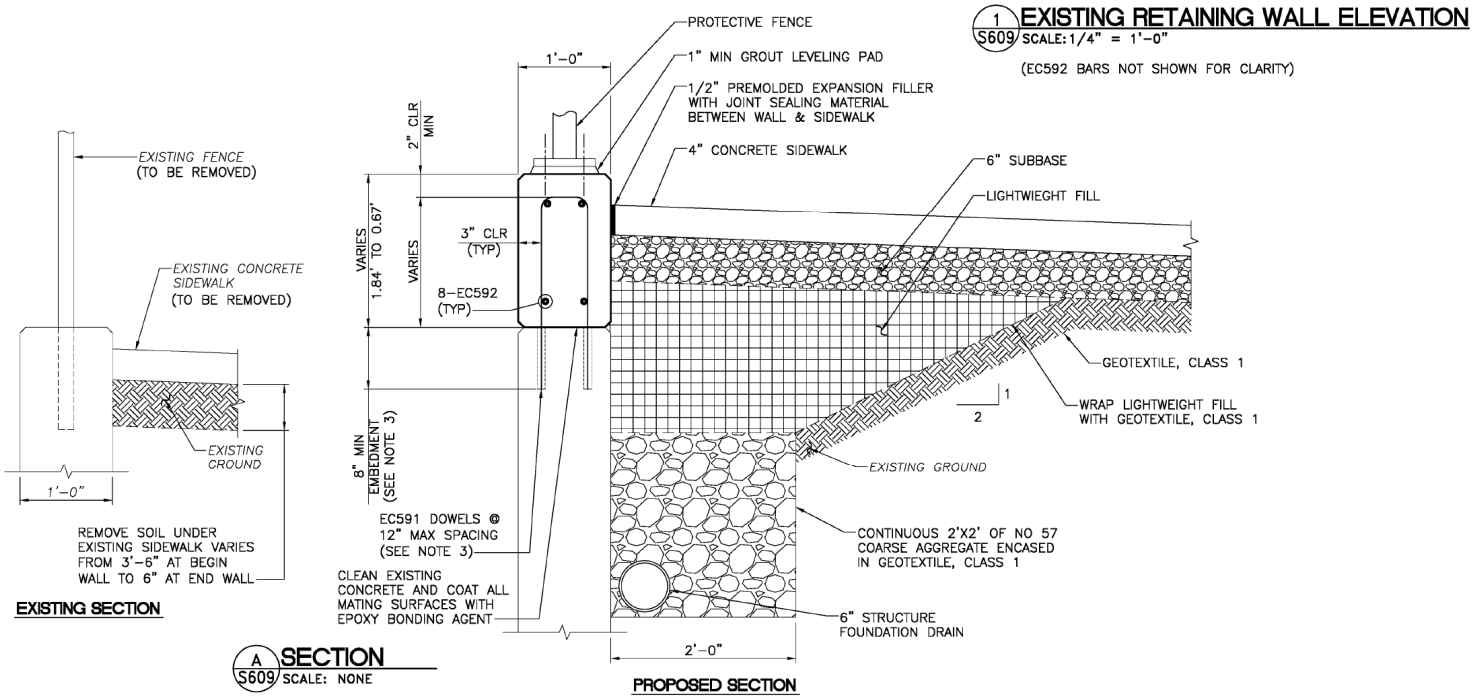
wittpenn BRIDGE REPLACEMENT

- First 450 CY Installed October 2017

Route 7 / Hackensack -- NJDOT

- Paved, Trafficked & Monitored, Shows No Movement

SEPTA –Media Line



Engineered Material

- Ultra Lightweight Material
- High Strength to Density Ratio
- High Friction Angle
- Freeze-Thaw Tested
- MSE Wall Tested
- Chemically Inert, UV Stable, Volume Stability
- Efficient Installation, Not Weather Sensitive

Thank You