GEOFOAM APPLICATIONS FOR GREEN INFRASTRUCTURE

Steven F. Bartlett, Ph.D., P.E.

https://www.sfb-engineering.com/bio

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BLOCK MOLDING PROCESS (CONT.)

raw styrene beads

steam expanded (1st steam heating)

EPS block density is controlled by the amount of styrene beads used to make the block. More beads produce higher density.

block molding (2nd steam heating)

block placement

EPS GEOFOAM ADVANTAGES

- EPS geofoam is extremely lightweight and sufficiently strong to support floor slabs, roadways, traffic, soil, landscaping and other equipment loads.
- EPS construction techniques allows accelerated construction, avoid of construction delays and other time and cost savings.
- EPS is easy to make, transport and place with trained workers
- EPS can be cut and shaped either at plant or on-site to create numerous architectural and landscaping profiles.
- EPS can create topography without adding significant load to underlying structures or utilities, etc.

SUMMARY OF EPS GEOFOAM PROPERTIES

Physical Properties of Foam-Control EPS Geofoam[1,2]								
TYPE - ASTM D6817		**EPS12**	**EPS15**	**EPS19**	**EPS22**	**EPS29**	**EPS39**	**EPS46**
Density, min.	lb/ft^3 (kg/m^3)	0.70 (11.2)	0.90 (14.4)	1.15 (18.4)	1.35 (21.6)	1.80 (28.8)	2.40 (38.4)	2.85 (45.7)
Compressive resistance @ 1% deformation, min.	psi psf (kPa)	2.2 320 (15)	3.6 520 (25)	5.8 840 (40)	7.3 1050 (50)	10.9 1570 (75)	15.0 2160 (103)	18.6 2680 (128)
Elastic Modulus	psi (kPa)	220 (1500)	360 (2500)	580 (4000)	730 (5000)	1090 (7500)	1500 (10300)	1860 (12800)
Flexural Strength min.	psi (kPa)	10.0 (69)	25.0 (172)	30.0 (207)	35.0 (240)	50.0 (345)	60.0 (414)	75.0 (517)
Water Absorption by total immersion, max.,	volume %	4.0	4.0	3.0	3.0	2.0	2.0	2.0
Oxygen Index, min.,	volume %	24.0	24.0	24.0	24.0	24.0	24.0	24.0
Buoyancy Force	lb/ft^3 (kg/m^3)	61.7 (990)	61.5 (980)	61.3 (980)	61.1 (980)	60.6 (970)	60.0 (960)	59.5 (950)

Source: ASTM D6817

DESIGN AND CONSTRUCTION CONSIDERATIONS

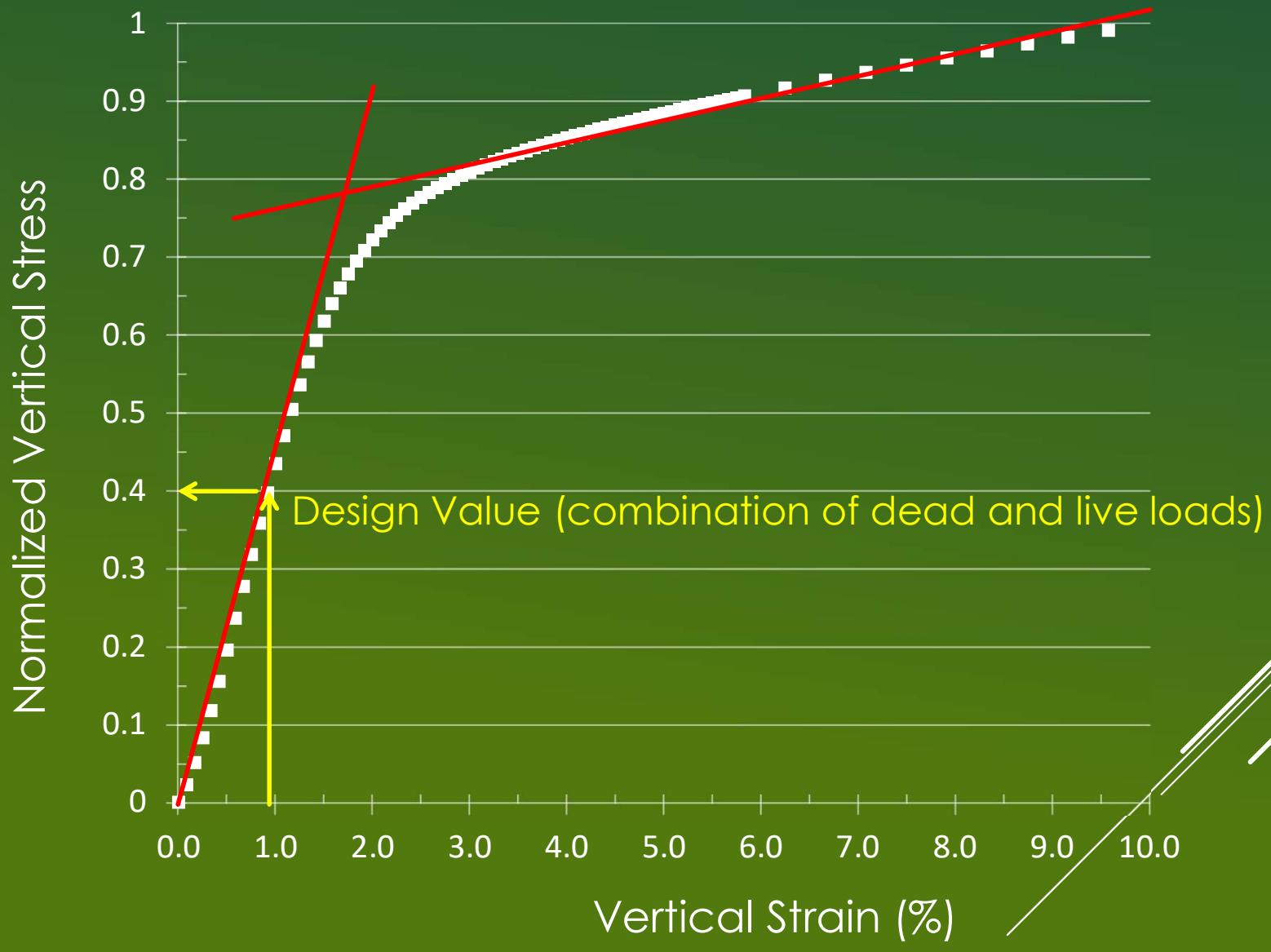
- Material Considerations
  - EPS Density
  - Compressive Strength
  - Insect Control
  - Flame Resistance
  - Moisture Absorption
  - Chemical Resistance

- Design Considerations
  - Dead Loads
  - Concentrated Loads
  - Integration with Pavement Systems
  - Seismic Loadings
  - Drainage / Buoyancy
  - Stability of Adjacent Ground
  - Settlement
  - Bearing Capacity

- Construction Considerations
  - Bedding Material
  - Compaction
  - Handling
  - Block Dimensions
  - Block Layout & Placement
  - Cover, Fire and UV protection

- Quality Assurance/Control
  - Specifications / Provisions
  - Testing and Sampling
  - Inspection
  - Corrective Action

STRENGTH AND COMPRESSIVE RESISTANCE



LIGHTWEIGHT, EASE OF TRANSPORT AND PLACEMENT

photo source:
geojuanjo.blogspot.com

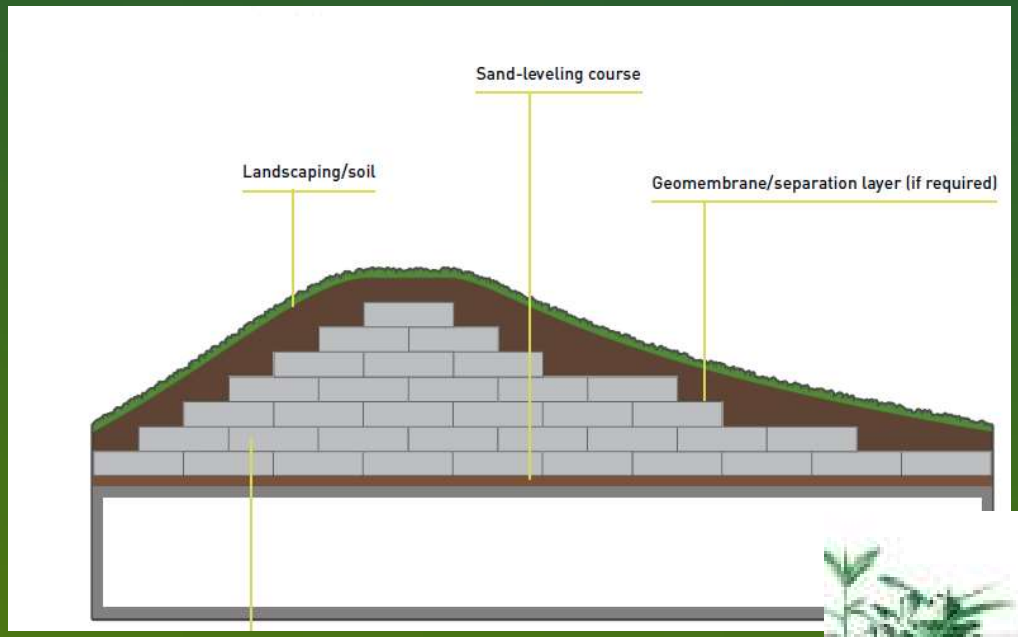
photo courtesy of
BASF- Kuala Lumpur,
Malaysia

photo courtesy of
http://www.architecture.org/

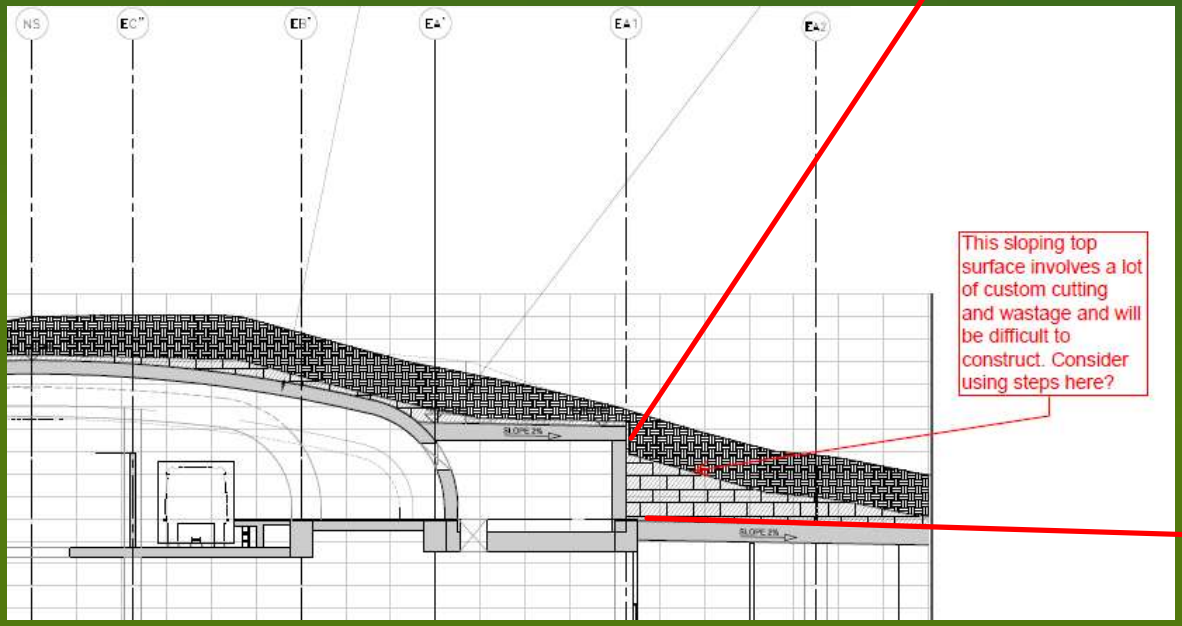
PRIMARY APPLICATIONS OF EPS GEOFOAM

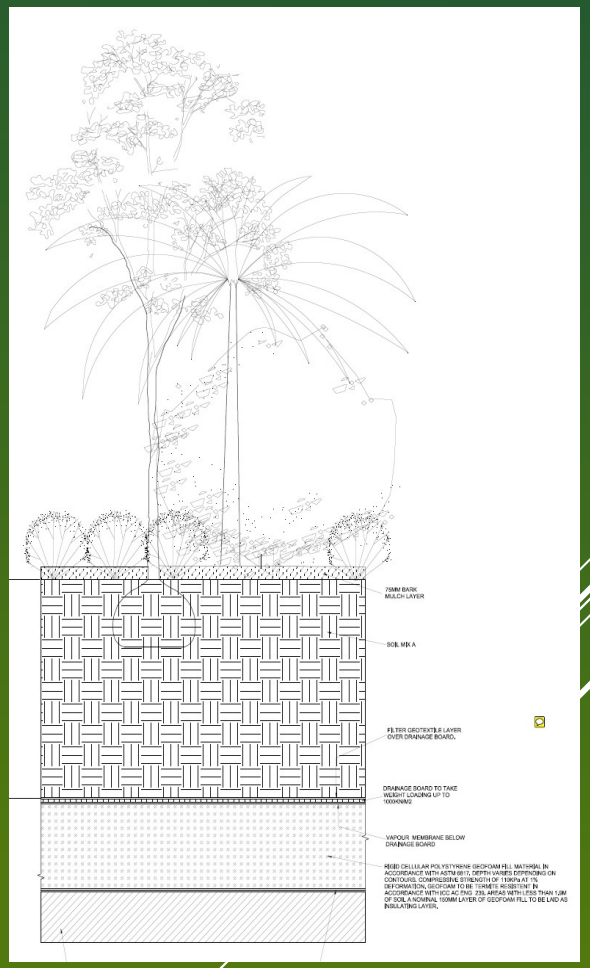
- Landscaping and Green roofs
- Lightweight fill and insulation against buried structures
- Culverts, pipelines, utilities
- Stadium and theater seating
- Airport runway and taxiways
- Roadway construction
- Rail embankment
- Bridge abutments
- Bridge underfill
- Accelerated bridge construction
- Compensating foundations
- Slope stabilization
- Retaining and buried wall backfill
- Raising of Leeves and Dikes
- Foundation for lightweight structures

LIGHTWEIGHT TERRAIN AND TERRACING



AIRPORT TERMINAL – JEDDAH

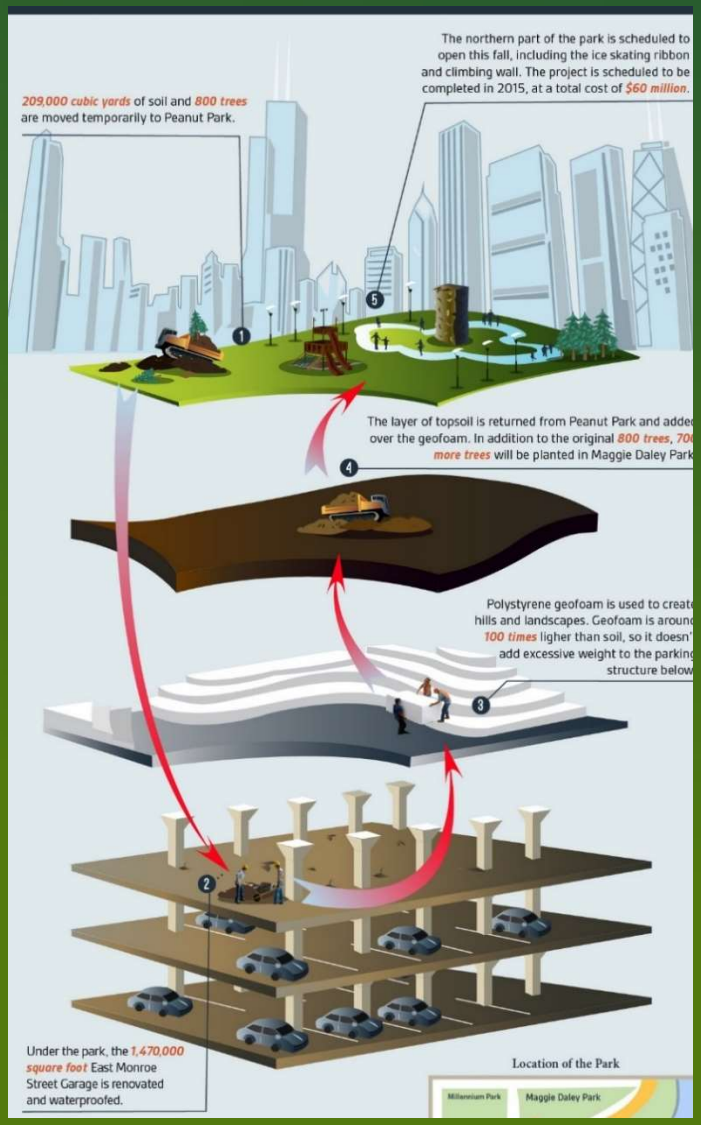




DESIGN CONSULTANT:

ATKINS

GREEN ROOF -MAGGIE DALEY PARK – CHICAGO



http://blog.geofoam.com/wp-content/uploads/sites/24/2014/11/maggiedaleyparkinfographic.jpg

http://www.architecture.org/

•Estimated Volume of Geofoam: 70,000 CY

ww.chicagoarchitecture.org

For more information, see

http://maggiedaleyparkconstruction.org/construction.php

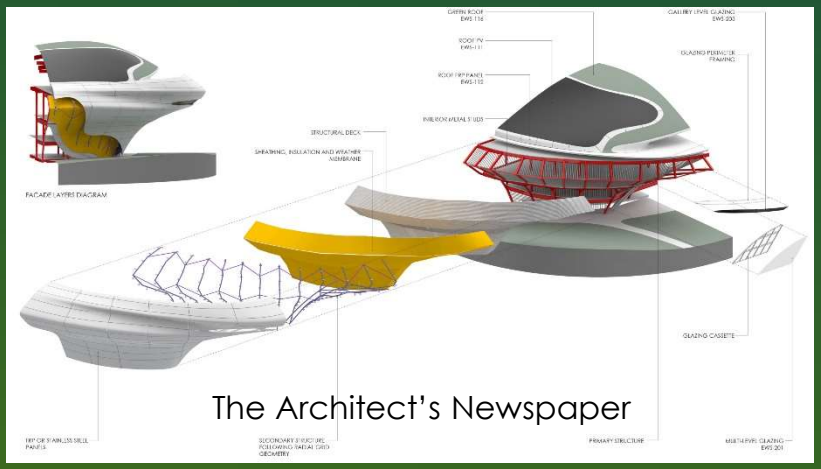
http://insulfoam.com/chicagos-maggie-daley-park-is-citys-largest-geofoam-project/

Oracle Group

INSULFOAM A CARLISLE COMPANY

TERRACES – DISNEY SHANGHAI – RECLAIMED GROUND

LUCAS MUSEUM GREEN ROOF — LOS ANGELES



https://lucasmuseum.org/building/

from Los Angeles Times

Video from Los Angeles Times

LUCAS MUSEUM TERRACES

South Park

South Park – Mirror Water Feature

Los Angeles Dept. of City Planning

Hydrotech™

GREEN ROOF – SALT LAKE CITY CONFERENCE CENTER

Conference Center, Salt Lake City, Utah

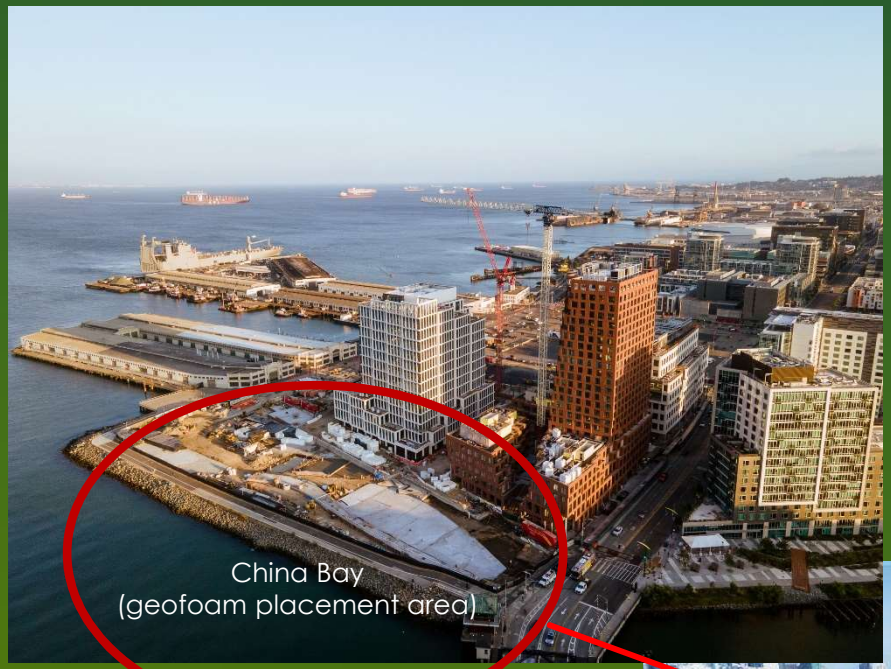
Conference Center, Salt Lake City, Utah

ATLAS

ACH FOAM TECHNOLOGIES

GROUND RECLAMATION - PARKS

Mission Rock Development, San Francisco, CA



TISHMAN SPEYER
Where Matters

PORT OF SAN FRANCISCO

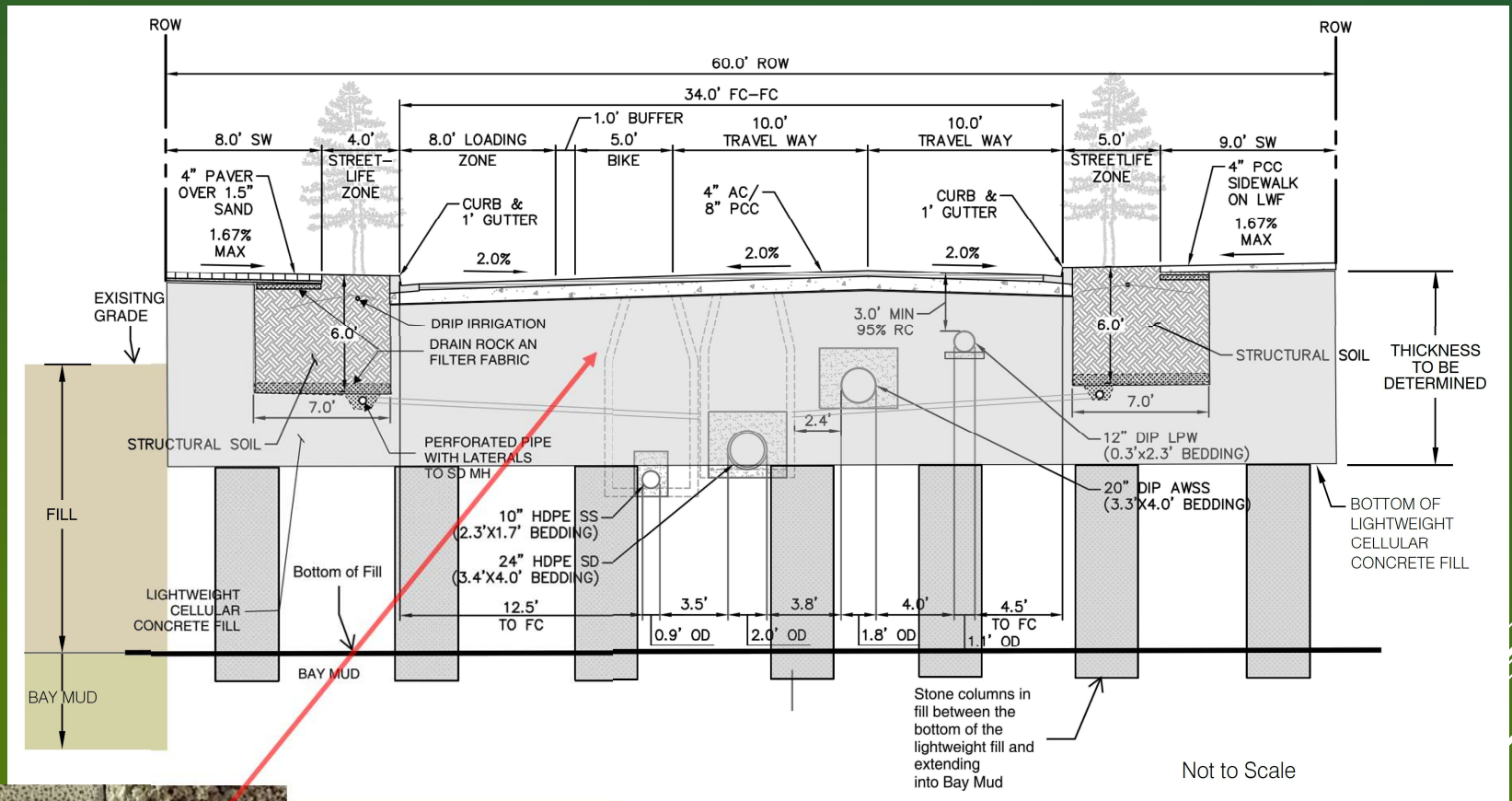
MISSION ROCK RESIDENTIAL

LANGAN

SGA

GROUND RECLAMATION - PARKS

Mission Rock Development, San Francisco, CA.



Lightweight Cellular Concrete was used instead of EPS for areas that would be permanently affected by sea elevation changes.

LANGAN

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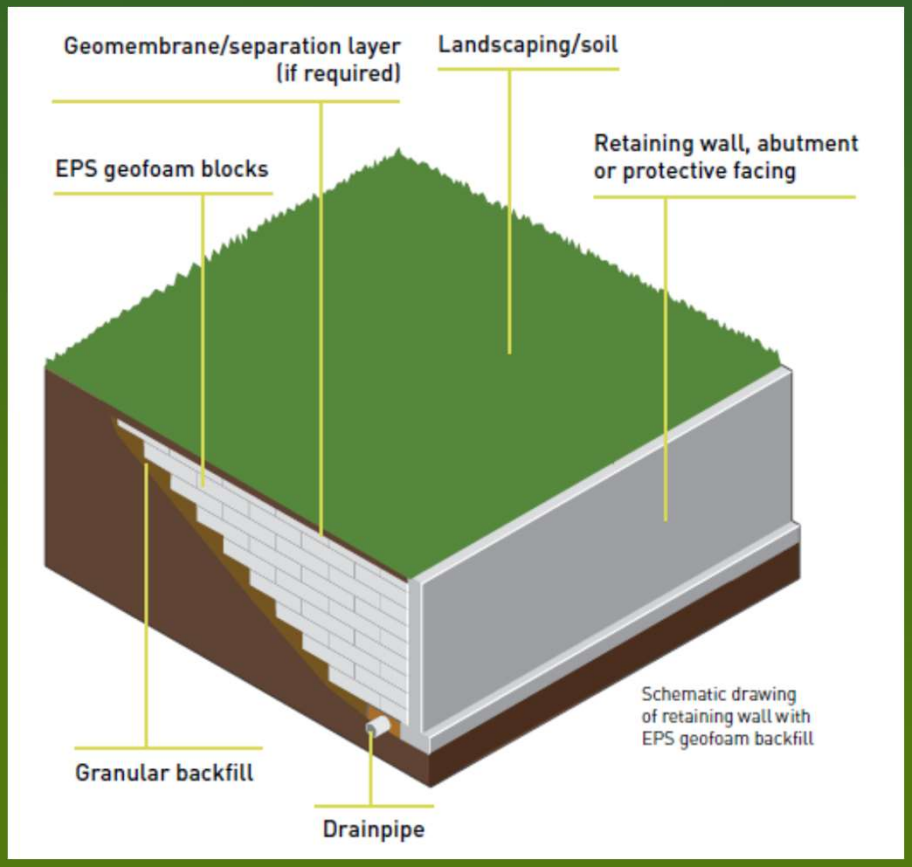
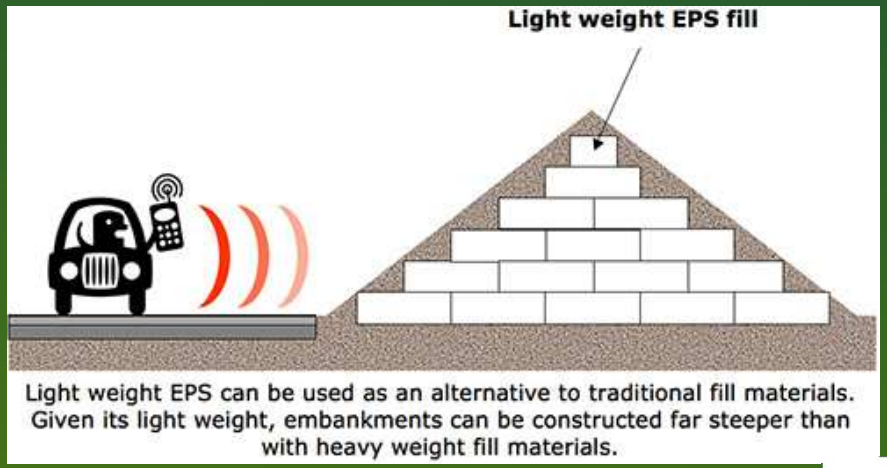
RETAINING & WALL BACKFILL

Reduction of Earth Pressures Against Structures



(EPS Geofoam Applications & Technical Data by EPSIA, 2012)

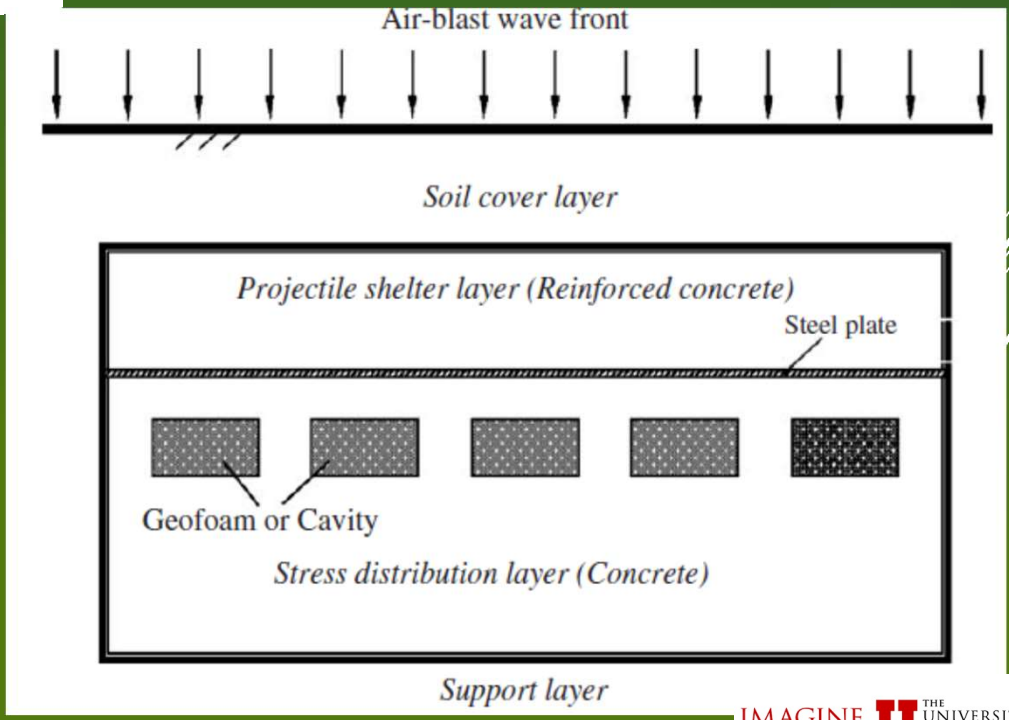
SOUND, BLAST AND ROCKFALL BARRIER



Light weight EPS can be used as an alternative to traditional fill materials. Given its light weight, embankments can be constructed far steeper than with heavy weight fill materials.

Sound and Blast Barrier

Blast Protection



BACKFILL, PLAZAS AND BLAST PROTECTION

http://www.asce.org/magazine/20140527-courthouse-takes-form-of-contemporary-cube/

U.S. FEDERAL COURTHOUSE, SALT LAKE CITY, UTAH

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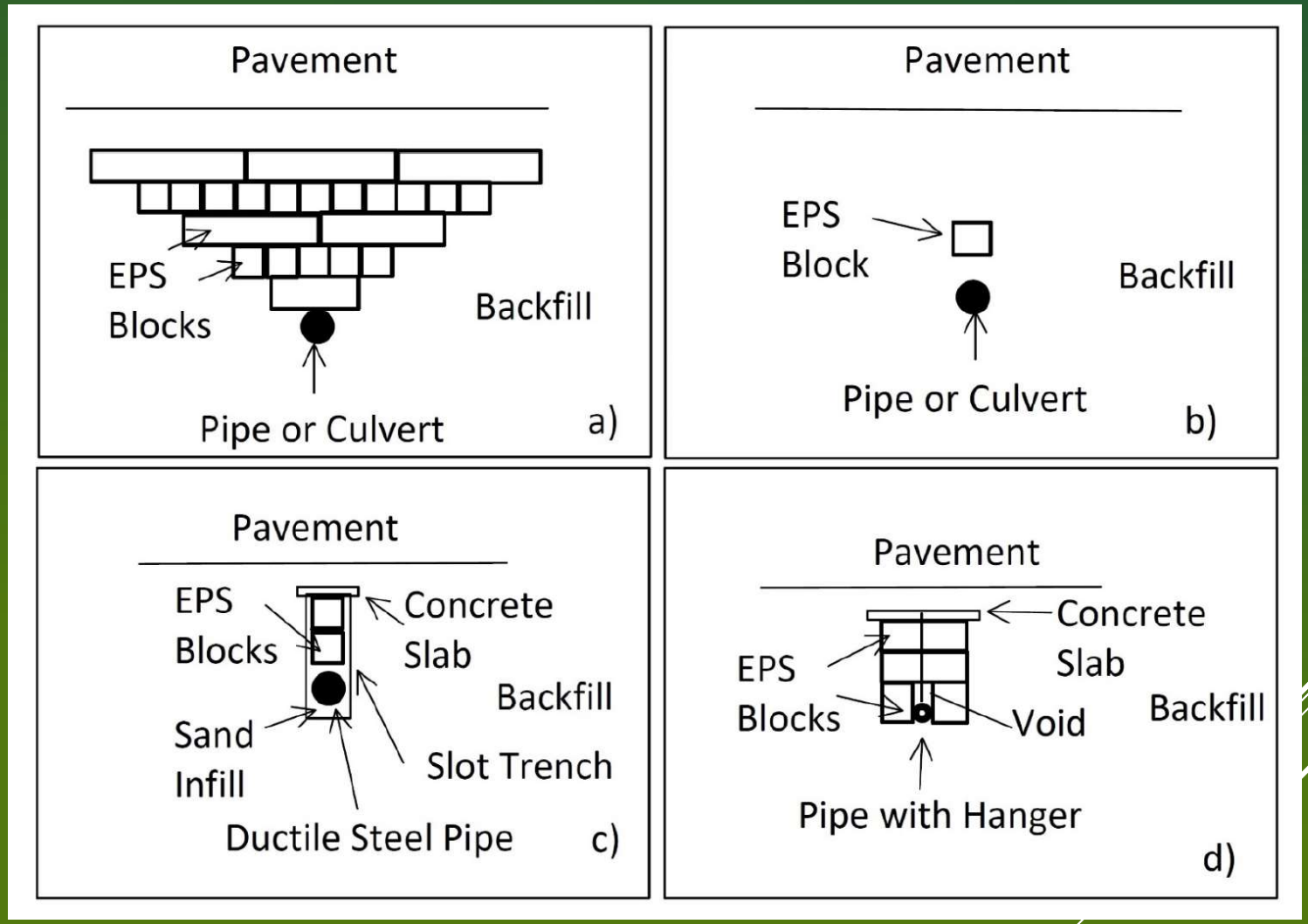
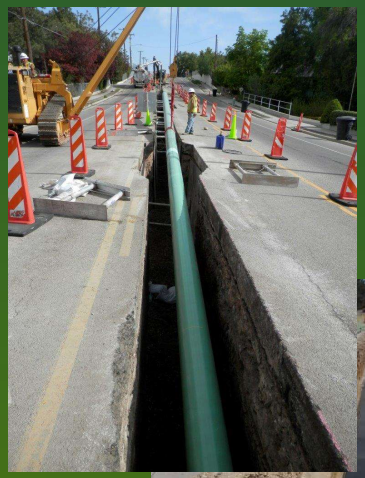
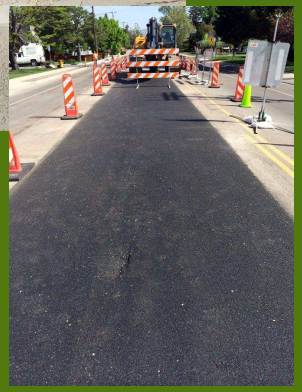
UTILITIES AND PIPELINES



CULVERTS, PIPELINES AND BURIED STRUCTURES





Dominion Energy®

UTA

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STADIUM AND THEATER SEATING

EPS Industry.org

EPS Industry Alliance
Geofoam Civil Engineering

AIRPORT RUNWAY FACILITIES

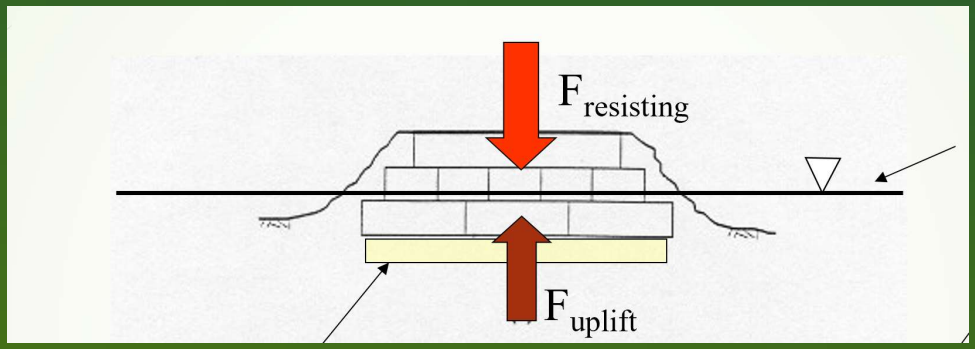
Oracle Group

MATERIAL AND CONSTRUCTION CONSIDERATIONS

- Buoyancy can be minimized by installing geofoam above the water table and ensuring suitable drainage. In addition, it can be counteracted by placing overlaying soils, pavements, sidewalks to sufficiently offset uplift forces resulting from buoyancy.
- Chemical resistance - EPS geofoam does not decompose nor is affected by road salts. Petroleum products and other chemicals can damage EPS, so incorporation of protective layers or barriers is used (e.g., soil cover, concrete slabs, geo-membranes, etc.).
- Flammability - EPS is combustible when exposed to an oxygen source, so it is important to cover with non-flammable materials (i.e., soil, etc.) and include a flame retardant. Geofoam is usually isolated by membranes, soils, or pavement in the finished application.

BUOYANCY CONSIDERATIONS

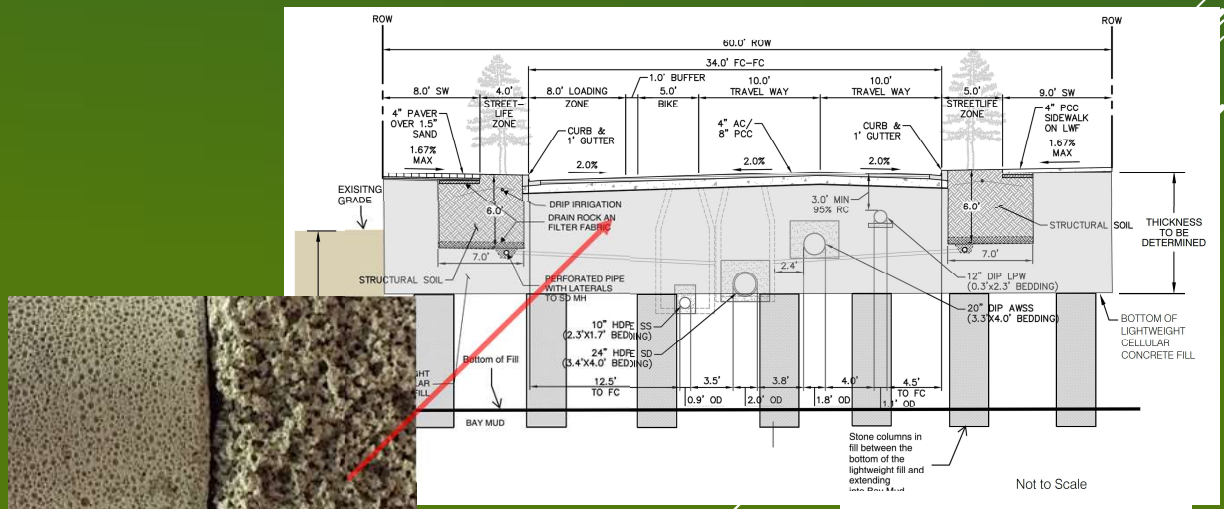
Option 1 - Use weight of EPS cover



Maximum groundwater level

F resting > 1.2 F uplift

Option 2 - Use permeable cellular concrete or granular material below the water table



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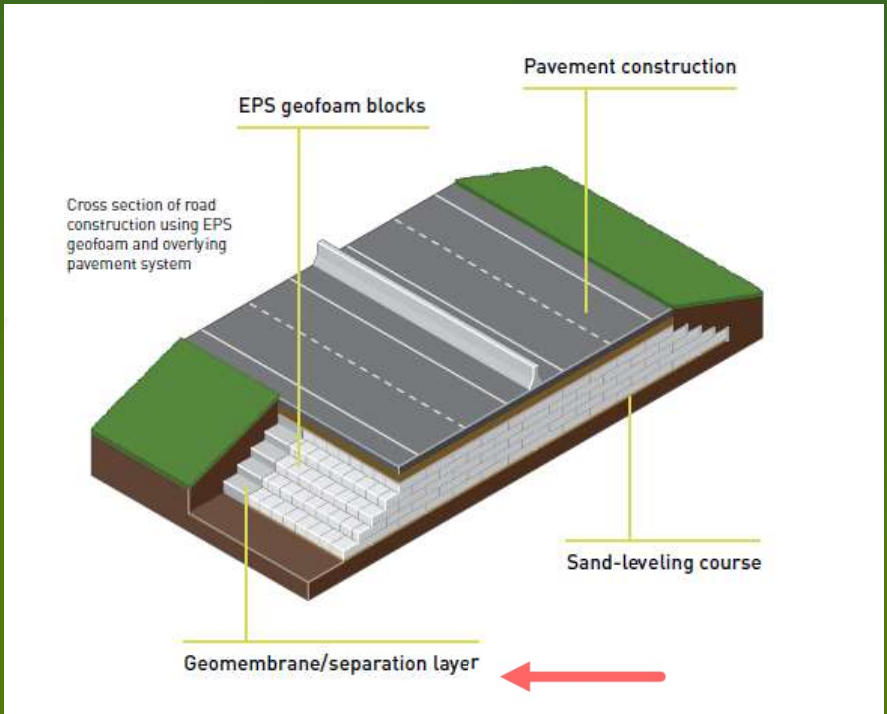
CHEMICAL RESISTANCE CONSIDERATIONS

(1) The possibility of petroleum spill is less because heavy truck and vehicle traffic is not present.

(2) The consequences of potential damage to the EPS are less because landscaping applications are less critical than roadway applications.



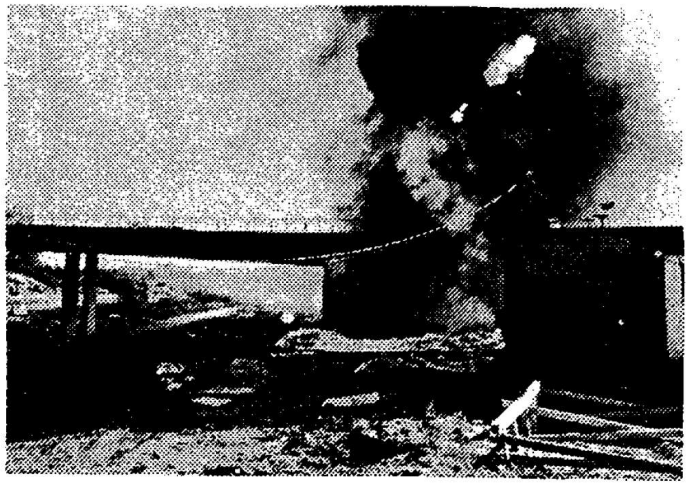
Method 1 – Sloped Embankment With Geomembrane Separation Layer

Method 2 – Vertical Embankment with concrete Load Slab and Precast ConcretePanels

Note Federal Highways Administration will accept either method

I-15 Reconstruction Geofoam Task Force Team

FLAMMABILITY CONSIDERATIONS



a) EPS embankment on fire. Knatten bridge, Norway.

Ordinary Expanded Polystyrene is a combustible material and will bum when set on fire. For this reason some precautions should be taken when constructing EPS fills using the normal quality material. Such precautions may include fencing in any stockpiles on site and provide round the clock guards, or place the blocks directly inn the fill as they arrive on site, working round the clock shifts if necessary.

Alternatively a self-extinguishing quality of EPS may be used at approximately 5 % increase in productions costs. Once the EPS is covered by the pavement material on top and soil on the side slopes, however, there will not be sufficient oxygen available to sustain a fire.

Two failures due to fires have occurred in Norway and were caused by welding activities on bridge abutments adjacent to EPS fills during the construction phase. . . . So the fire potential should not be overlooked and in some counties in Norway the local highway offices are using self-extinguishing material at the somewhat higher cost in order to exclude fire hazards. A third fire incident is reported from Japan. (Proceedings of EPS 1996 – Japan)

FLAMMABILITY CONSIDERATIONS

Step 1 – Use Flame Retardant Additive

EPS Fire Resistance

The primary flame retardant currently used in EPS foam insulation is HBCD. Hexabromocyclododecane (HBCD) is an additive flame retardant that promotes increased fire resistance in EPS building and construction applications. This allows EPS foam insulation to meet the stringent fire safety requirements governed by the International Code Council and National Building Code of Canada, providing increased protection to buildings and building occupants. HBCD has also been used as a flame retardant in solid plastics such as high impact polystyrene and in carpets, upholstery and other textiles.

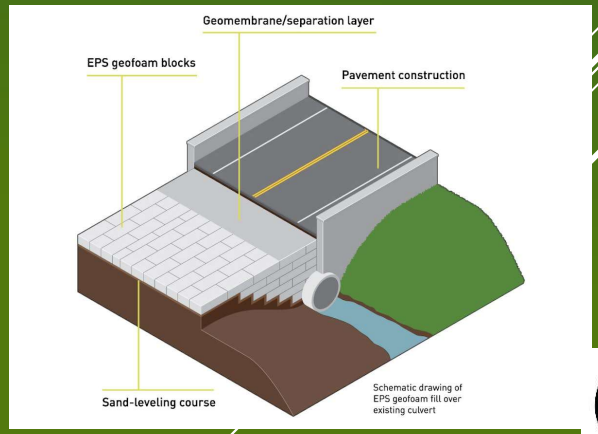
SIPA Structural Insulated Panel Association

Step 2 - Construction Precautions

- Prohibit smoking or any other ignition sources near the EPS block storage and staging area at the job site.
- Keep all sources of ignition away from the installed geofoam area, such as:
  - Welding
  - Open flames
  - Cutting torches
  - Cutting or grinding tools
  - Sources of static or electrical discharge

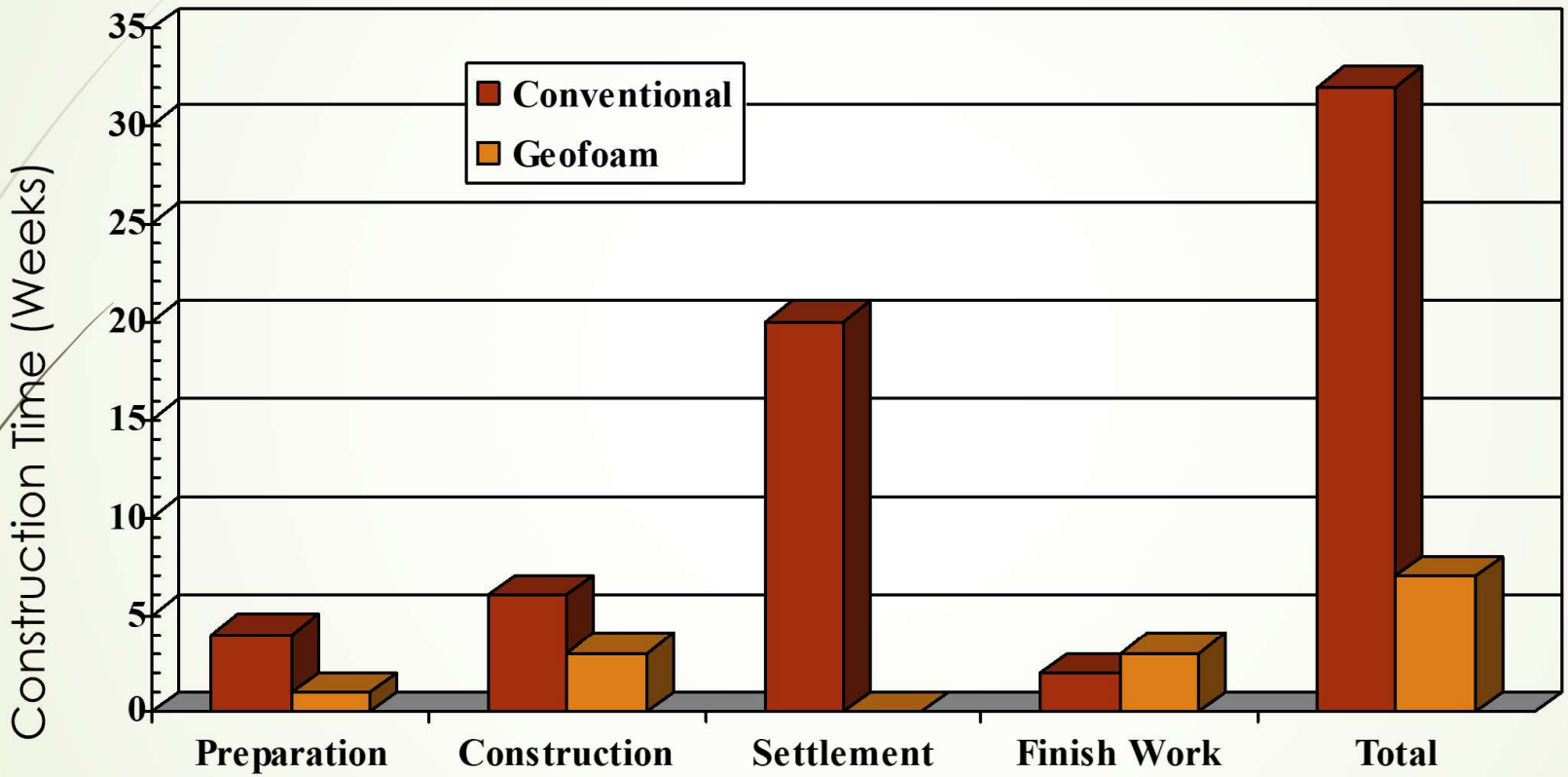
EPS Industry Alliance

Step 3 – Cover/Incapsulate Block



SGA

SCHEDULE COMPARISON



Typical Construction Time from I-15 Project

COST COMPARISON

Geotechnology	Various construction activities (*With typical unit cost*)	Associated costs (Year 2000)
Lime cement columns	Existing embankment removal ($6/m^3)	$9,500
	Lime cement column installation (0.8 m *column*—$17.5/m, 0.6 m *column*—$16/m)	$97,000
	One-stage MSE wall/embankment construction ($200/m^2 *wall face*)	$43,500
	One-stage embankment construction, surcharging, settlement, and removal (*placement*—$9/m^3, *removal* $6/m^3)	$10,000
	Total=	**$160,000**
Geofoam	Existing embankment removal ($6/m^3)	$1,500
	Bedding sand ($7/ton, *with 1 crew 1* week)	$5,500
	Geofoam embankment ($45/m^3)	$65,000
	Tilt-up panel wall ($200/m^2 *wall face*)	$20,000
	Load distribution slab ($60/m^2 *surface area*)	$23,000
	Embankment above geofoam ($9/m^3)	$5,000
	Total=	**$120,000**
Two-stage MSE wall	Existing embankment removal ($6/m^3)	$9,500
	Bedding sand ($7/ton, *1 crew 2* days)	$2,500
	PV drain installation (1.5 m triangular spacing) ($1.5/m *without predrilling*, $3/m *with predrilling*)	$14,000
	Wall/embankment construction and settlement time ($300/m^2 *wall face*, $9/m^3 *embankment*)	$54,000
	Three-stage embankment construction, surcharging, settlement time, and removal (*placement*—$9/m^3, *removal* $6/m^3)	$20,000
	Total=	**$100,000**

The above costs do not include utility relocation costs.
If utilities are present then geofoam is the low cost alternative

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AWARDS

ASCE 2002 Outstanding Civil Engineering Achievement (OPAL) Award, Wasatch Constructors I-15 Reconstruction Design-Build Team, Salt Lake City, Utah

ACEC Arizona 2006 Grand Award, Rockfall Containment and Safety, SR 264 at 2nd Mesa, Arizona

ASCE 2010 Local Outstanding Civil Engineering Achievement Awards, Geotechnical Category – Outstanding Award SR 519 / I-90 to SR 99, Intermodal Access I/C Improvements Phase 2 Design Build Project Seattle, Washington

Rebuilding America's Infrastructure Magazine 2012, Best of America's Infrastructure – Cost Saving Approaches, Geofoam Embankments, UTA TRAX line, Salt Lake, City, Utah

REUSE AND RECYCLING

Growing New Ideas

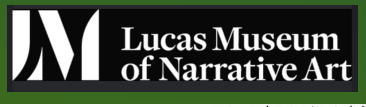
EPS is recyclable. EPS saves energy. EPS saves resources. EPS-IA members are vested in product stewardship that supports a circular economy, and they thrive on innovation to support ecological advantages. Versatile, reliable and available in a wide range of applications, EPS ensures safe transportation of the things we value and delivers maximum comfort and efficiency at home and work. The EPS industry is constantly working on new approaches to improving its protection, its recyclability and its insulation properties even more.

Despite ongoing misperceptions about its recyclability, EPS recycling is well established and consistently maintains one of the highest recycling rates among all plastics. For more than 30 years local community programs, in conjunction with recycling initiatives from large companies that use EPS packaging, have proven that creative and collaborative solutions provide positive results. With regular, recycled-content or biodegradable feedstocks, EPS foam has low global warming potential, low embodied energy and has developed recycled-content resin formulations.

https://www.epsindustry.org/eps-sustainability

EPS Industry Alliance
Geofoam Civil Engineering

PARTNERS

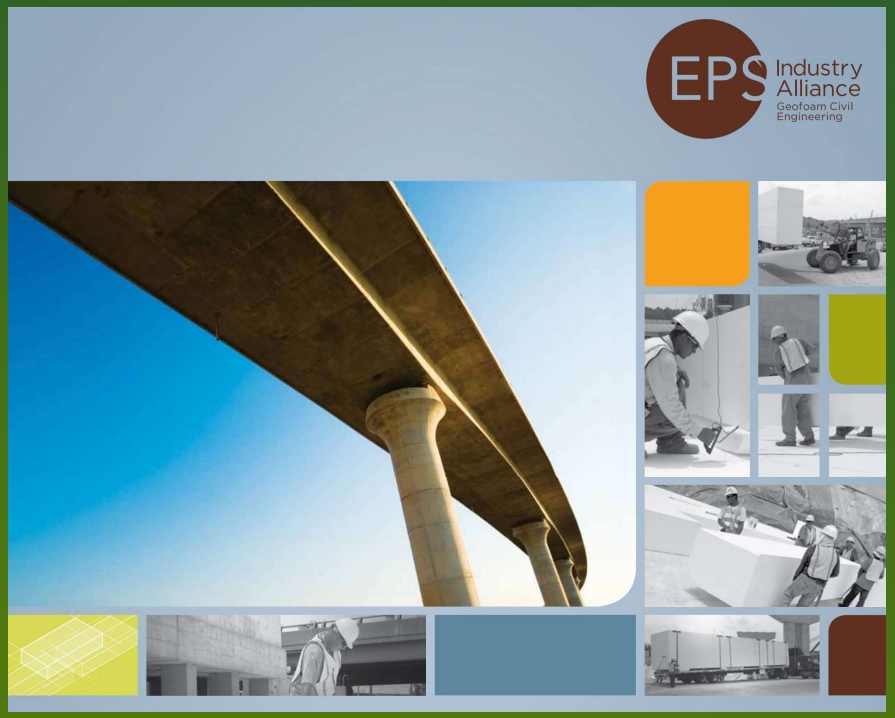


KINGDOM OF SAUDI ARABIA
MINISTRY OF DEFENCE AND AVIATION
GENERAL AUTHORITY OF CIVIL AVIATION
KING ABDULAZIZ INTERNATIONAL AIRPORT
DEVELOPMENT PROJECT

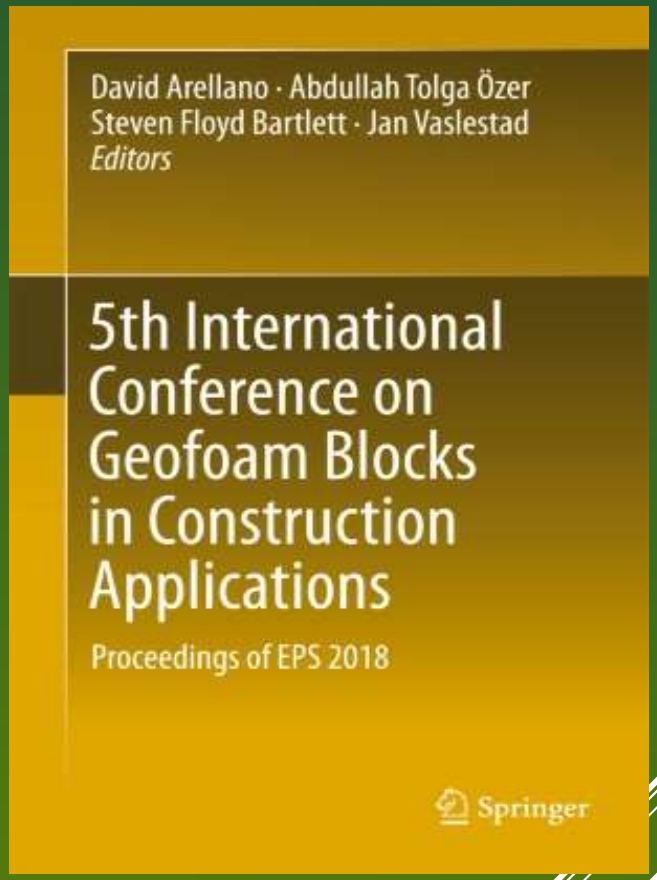
المملكة العربية السعودية
وزارة الدفاع والطيران
الهيئة العامة للطيران المدني
مشروع تطوير مطار الملك عبد العزيز الدولي

DESIGN CONSULTANT:

RESOURCES



https://www.geofoam.com/?pdf=EPS-Geofoam-Applications-Technical-Data.pdf&id=968



https://www.springerprofessional.de/en/5th-international-conference-on-geofoam-blocks-in-construction-a/15790828?tocPage=1

Authors: Stark, Bartlett and Arellano, 2012