LIGHTWEIGHT ADVANTAGE

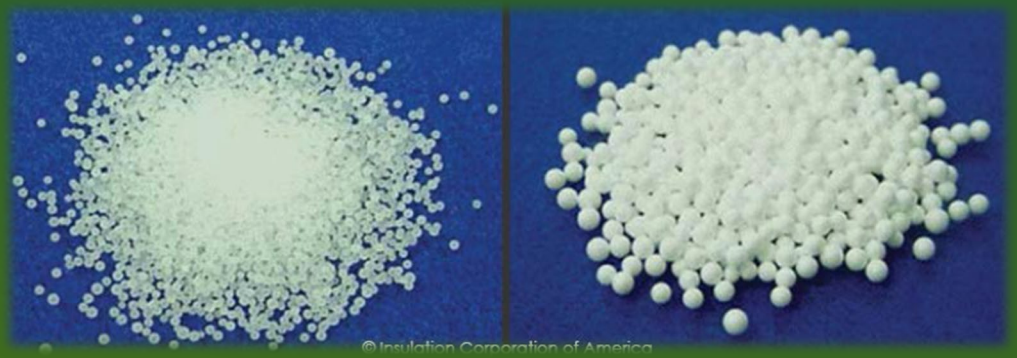
EPS GEOFOAM APPLICATIONS FOR COASTAL INFRASTRUCTURE

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

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

IMAGINE THE UNIVERSITY OF UTAH

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.

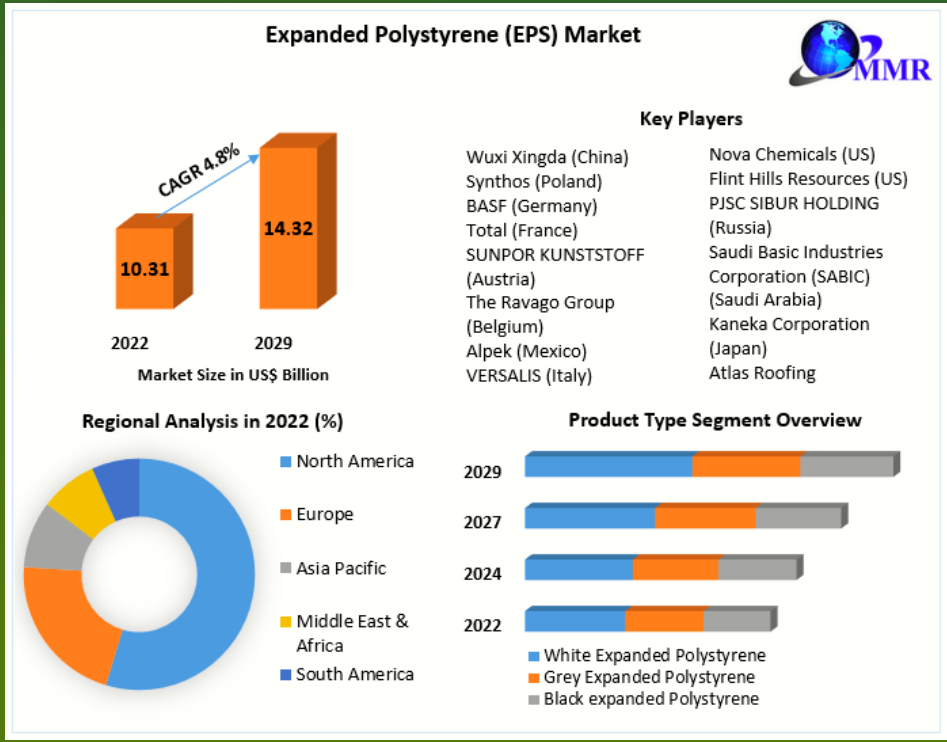
block molding (2nd steam heating)

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.

EPS GEOFOAM DEVELOPMENT



- 1972 Norway (Bridge Approach Construction)
- 1985 Norway, Oslo (1st International EPS Conference)
- 1980's Japan created EPS Development Organization
- 1990's U.S had first EPS roadway projects
- 1996 Japan, Tokyo (2nd International EPS Conference)
- 1998 U.S. Winter Olympics, Salt Lake City (Largest EPS project worldwide)
- 2001 U.S. , Salt Lake City (3rd International EPS conference)
- 2011 Norway, Lillestrom (4th International EPS conference)
- 2018 Turkey, Cyprus (5th International EPS conference)

Countries with EPS projects

Czech Republic, Denmark, Finland, France, Germany, Turkey, Saudi Arabia
Greece, Ireland, Italy, Netherlands, Norway, Poland, Russia, Serbia, Sweden, The UK, India, China, Malaysia, Thailand, The Philippines, South Korea, Taiwan, Australia, South Africa

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

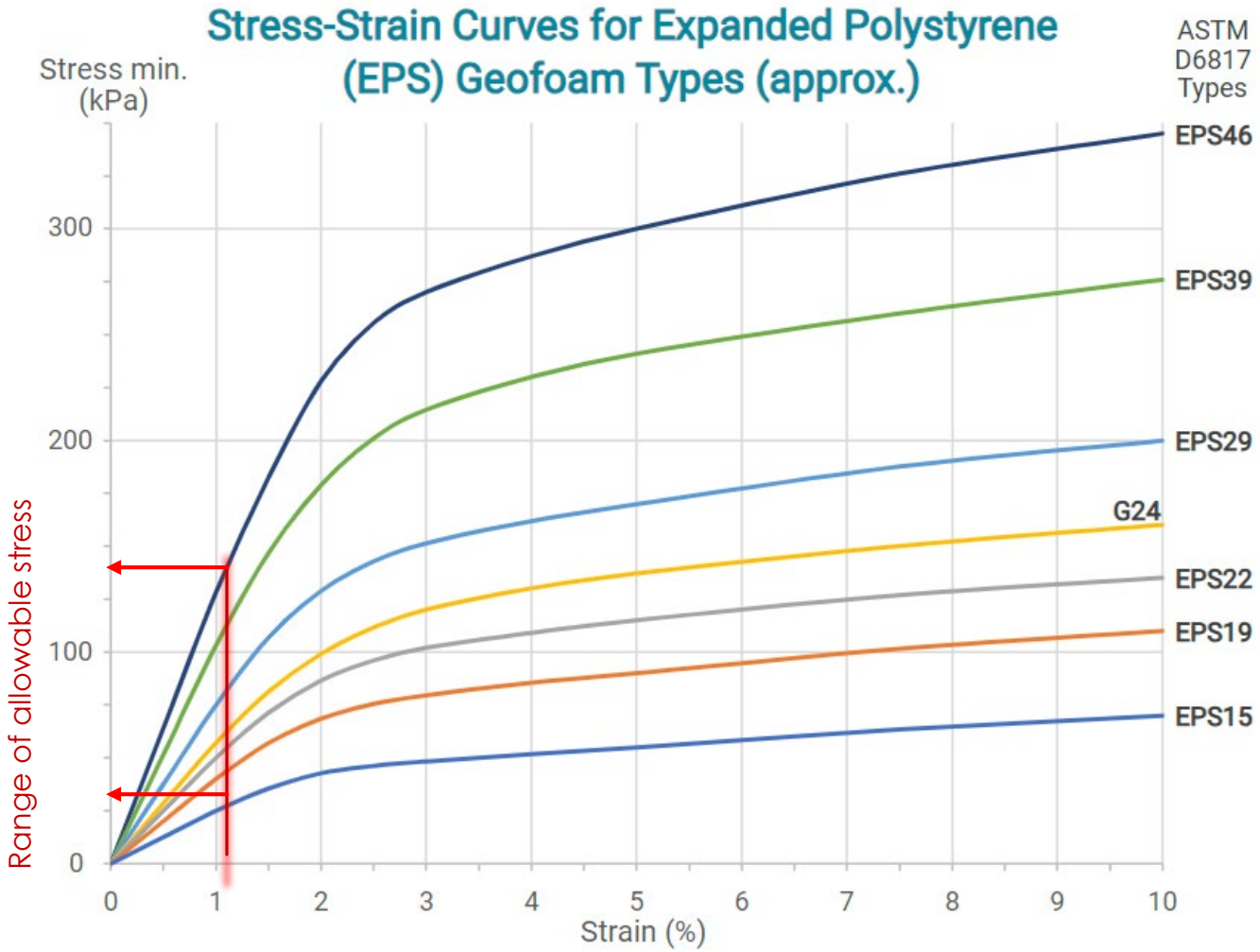
- Quality Assurance/Control
  - Specifications / Provisions
  - Testing and Sampling
  - Inspection
  - Corrective Action

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

STRENGTH AND COMPRESSIVE RESISTANCE



1% Design value for compressive loads (combined dead & live loads

LIGHTWEIGHT, EASE OF TRANSPORT AND PLACEMENT

photo source:
geojuanjo.blogspot.com

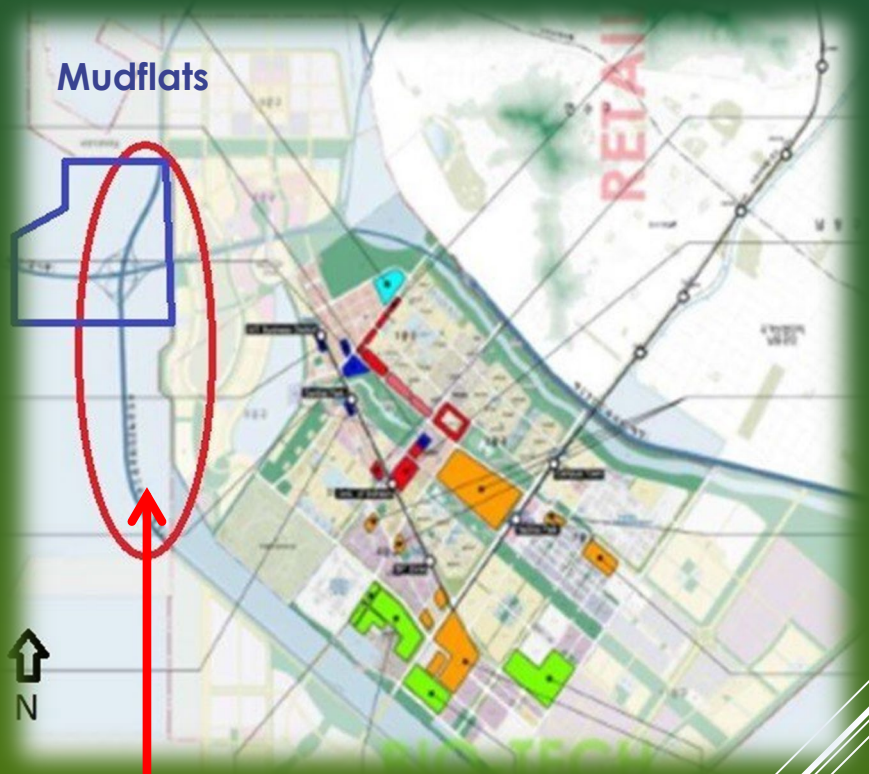
photo courtesy of
BASF- Kuala Lumpur,
Malaysia

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

PRIMARY APPLICATIONS OF EPS GEOFOAM

- Coastal Engineering
  - Enclosures, Tunnels, Walkways, Parks, Green Roofs
  - Roadway Over Reclaimed Land
  - Bridges on Soft Soil
  - Floating Roadways and Bridges
  - Floating Platforms and Lightweight Buildings
  - 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

Enclosures, Tunnels, Walkways, Parks



Elevated Highway & Interchange over the mudflats

- Ecological impact to mudflats
- Visual Impact
- Traffic Sound
- Air Pollution

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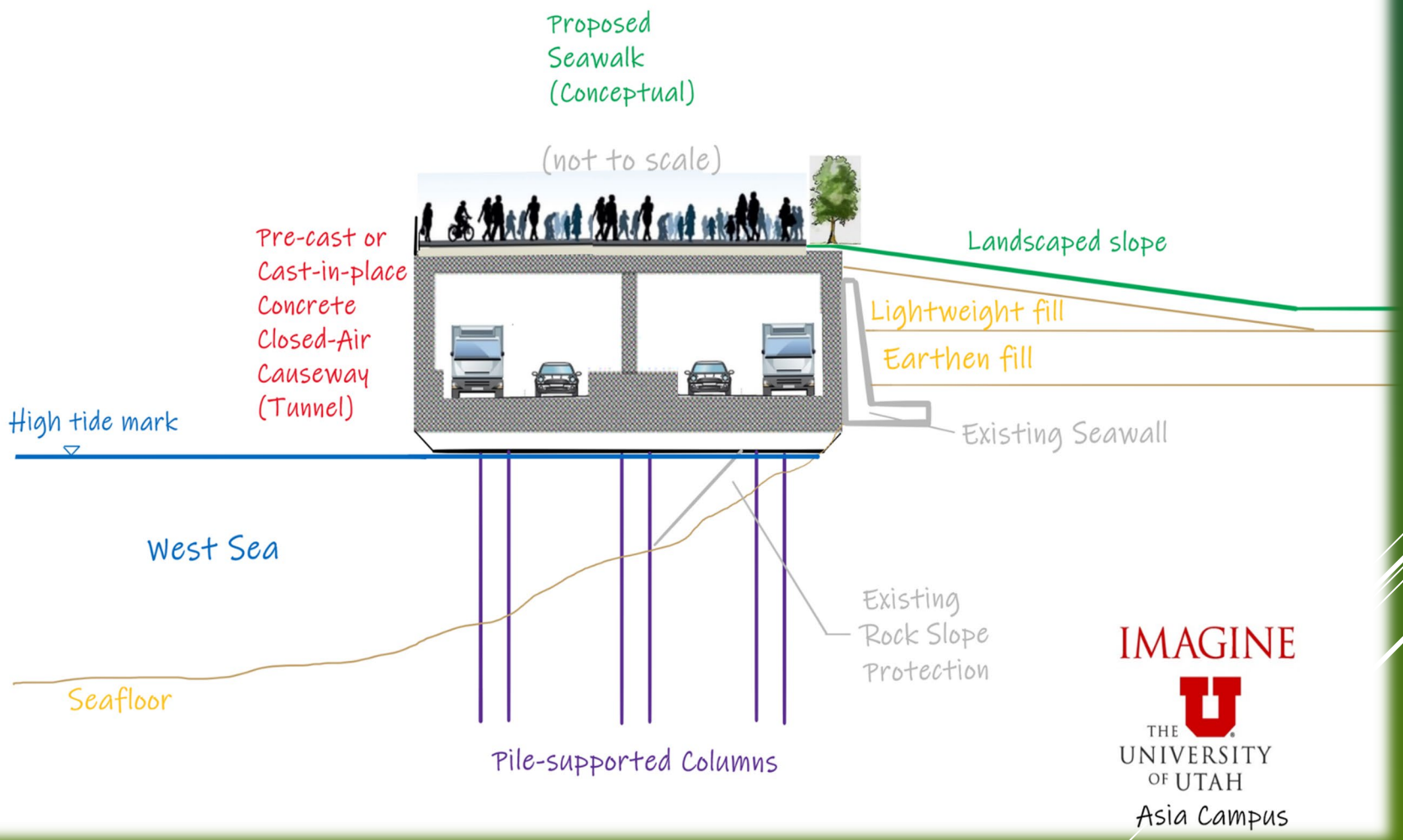
Enclosures, Tunnels, Walkways, Parks

CASE STUDIES / M-Rio, Madrid, Spain

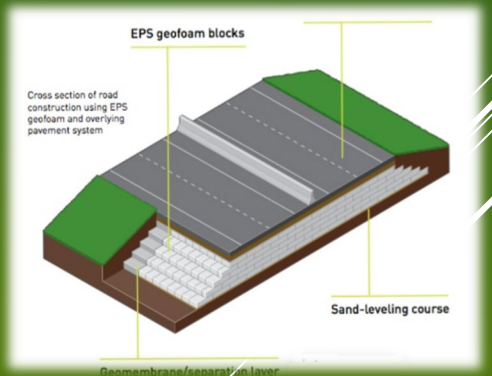
IMAGINE THE U UNIVERSITY OF UTAH

Enclosures, Tunnels, Walkways, Parks



PROPOSED SEAWALK CROSS-SECTION

Enclosures, Tunnels, Walkways, Parks



POSSIBLE LANDSCAPING AND PARK CONCEPTS

https://www.sfb-engineering.com/global-engineering-blog

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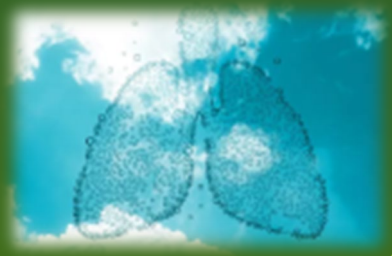
Enclosures, Tunnels, Walkways, Parks



Improved
Air Quality

Protect Sensitive
Ecosystem
(Mudflats)

Eliminate Noise &
Improve Serenity

Preserve & Create
Inspiring Vistas

COMMUNITY WELLNESS

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Enclosures, Tunnels, Walkways, Parks

Mission Rock Development, San Francisco, CA

TISHMAN SPEYER
Where Matters

PORT OF SAN FRANCISCO

MISSION ROCK
RESIDENTIAL

LANGAN

SGA

TERRACES – DISNEY SHANGHAI – RECLAIMED GROUND

Fantasyland

Tomorrowland

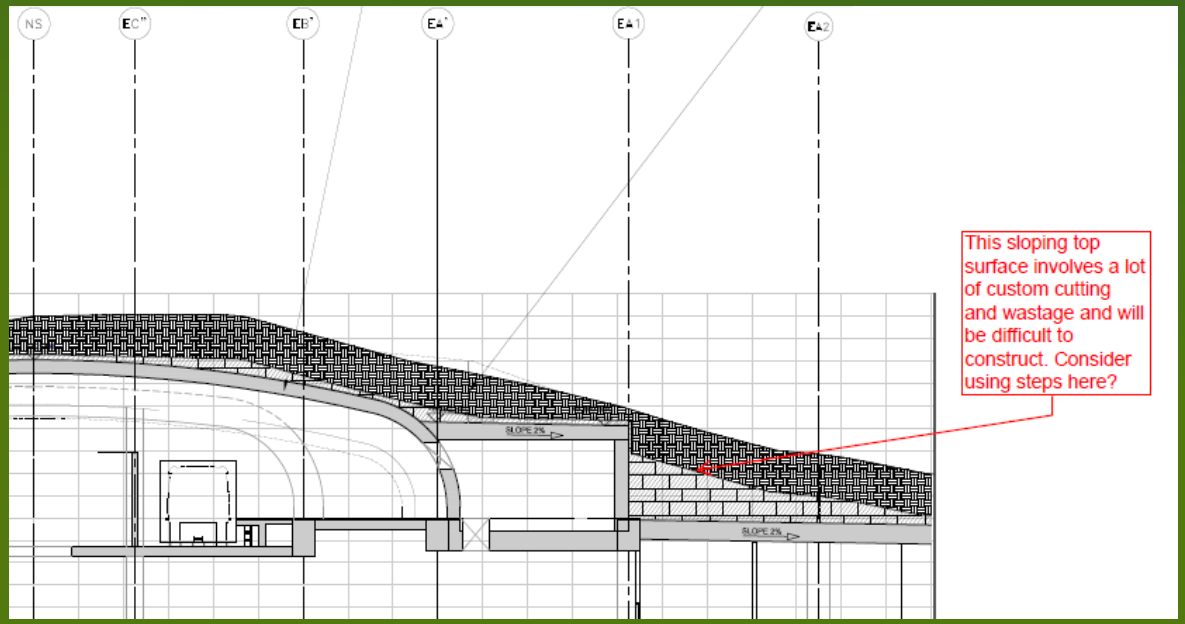
Disney

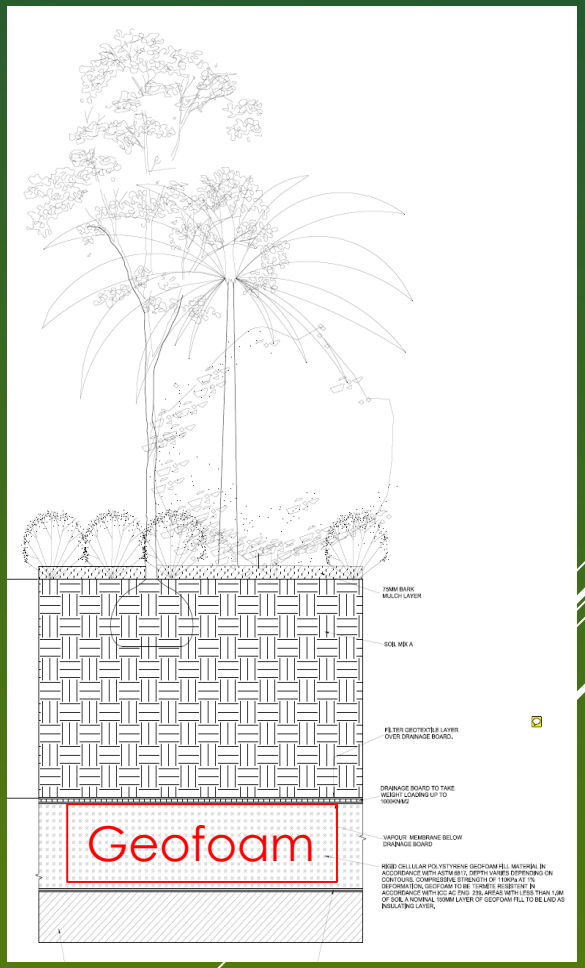
BROADWAY

AFM CORPORATION

SGA

GREEN ROOF - AIRPORT TERMINAL – JEDDAH

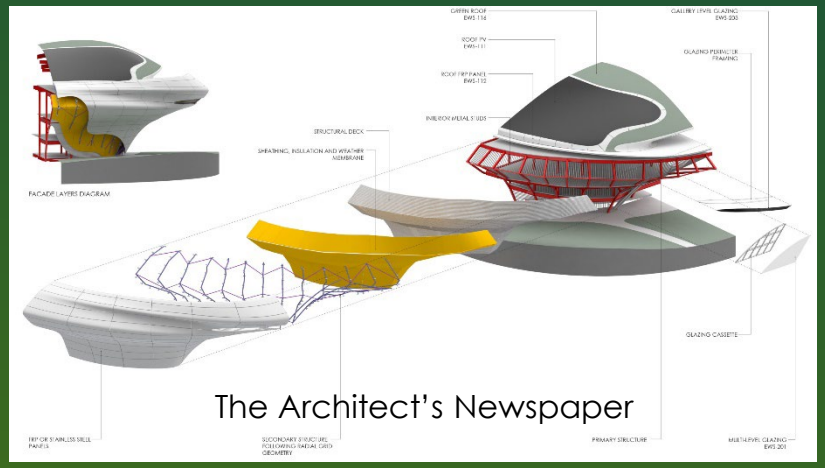




DESIGN CONSULTANT:

ATKINS

GREEN ROOF – LUCAS MUSEUM



https://lucasmuseum.org/building/

from Los Angeles Times

Video from Los Angeles Times

Hydrotech

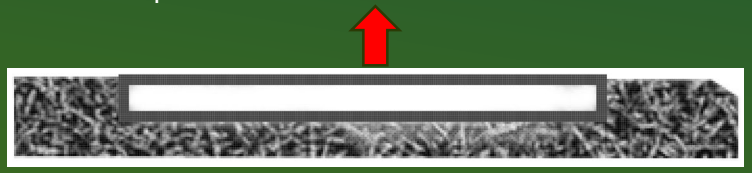
Lucas Museum of Narrative Art

Stantec

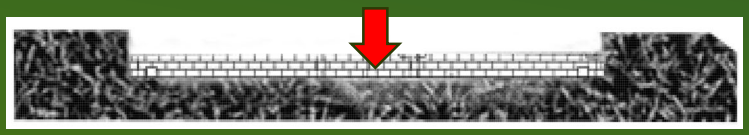
ROADWAYS OVER RECLAIMED LAND

RAPID CONSTRUCTION - ZERO NET LOAD WITH GEOFOAM

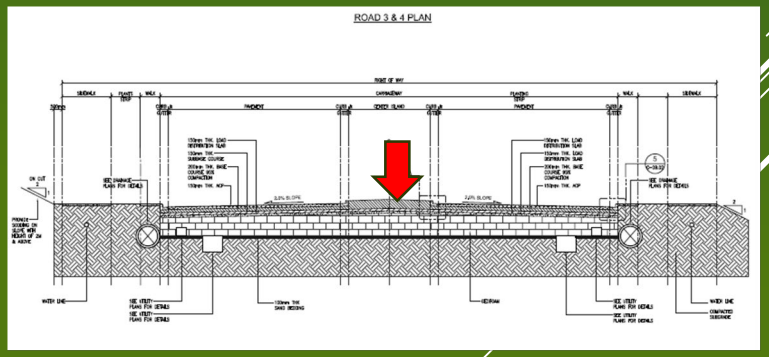
1) Subexcavation = weight of new pavement section



2) Partial replacement with EPS blocks



3) Construction of final roadway



Reclaimed Land – Manila Philippines

BRIDGES ON SOFT SOIL

UTA –Light Rail – Salt Lake City, Utah

ACCELERATION BRIDGE CONSTRUCTION WITH EPS

Lokkeberg Bridge, Norway

Truss or Modular Bridge

Pavement

Bridge Footing

EPS Blocks

EPS Blocks

EPS Blocks

EPS Blocks

Lateral Restraint Cable System

Concrete Slab

Soft Soil

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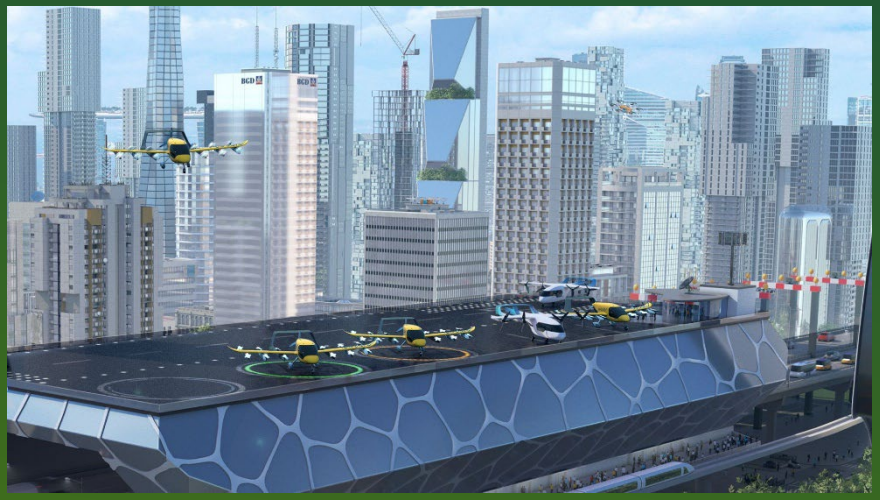
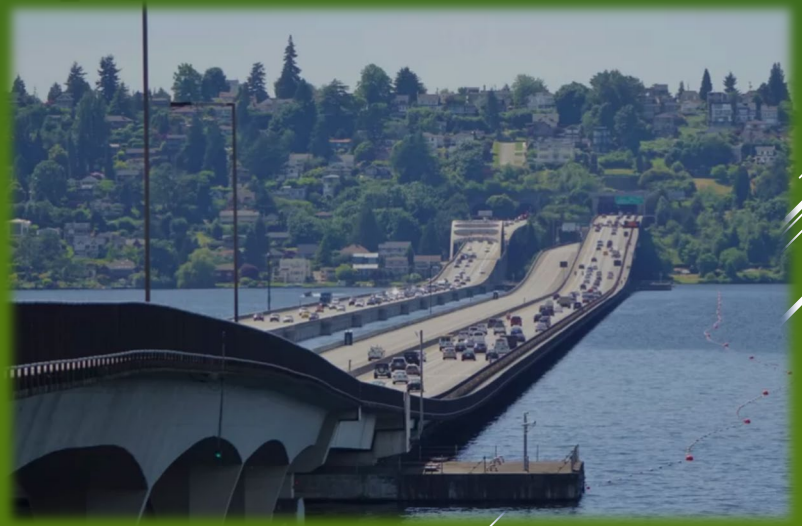
FLOATING TRANSPORTATION FACILITIES

Shiziguan Forest floating bridge in China



Vertiport," or landing site for autonomous flying taxis. Image courtesy of Boeing

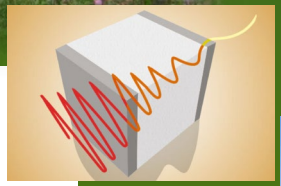
Geofoam Floating Helipad: Courtesy of airfoam



Mercer Island Bridge, Seattle, Washington

FLOATING PLATFORMS AND BUILDINGS

The Coeur d'Alene Resort, Idaho



SIP[illegible]nt more energy efficient than conventional buildings

Antelope Point Marina, Lake Powell

CONSTRUCTION OF FLOATING PLATFORMS

http://amphibioushomes.weebly.com/floating-foundations--bases.html

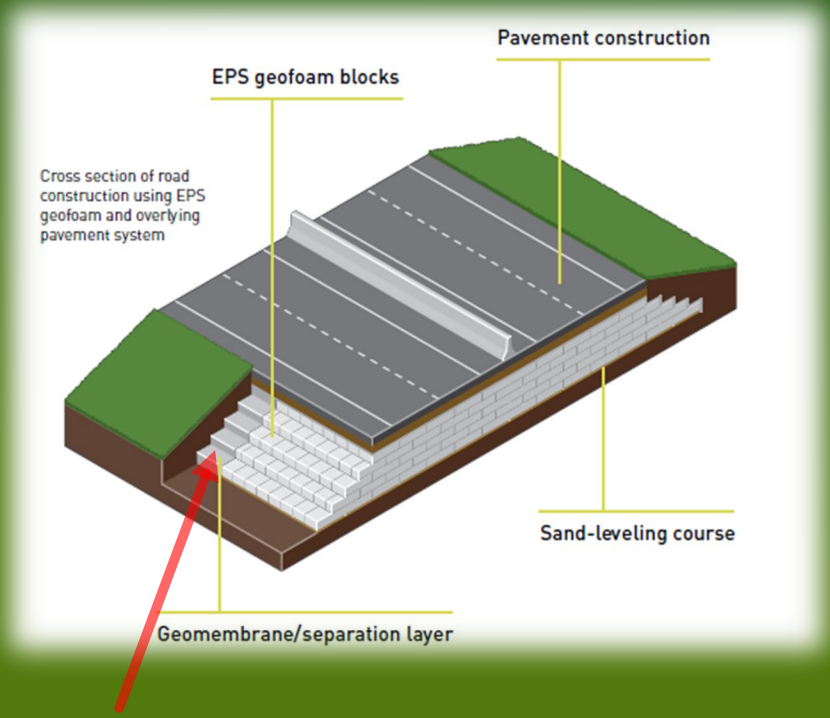
MATERIAL AND CONSTRUCTION CONSIDERATIONS

- 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.

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 capped with concrete load distribution slab (LDS) and precast concrete panels

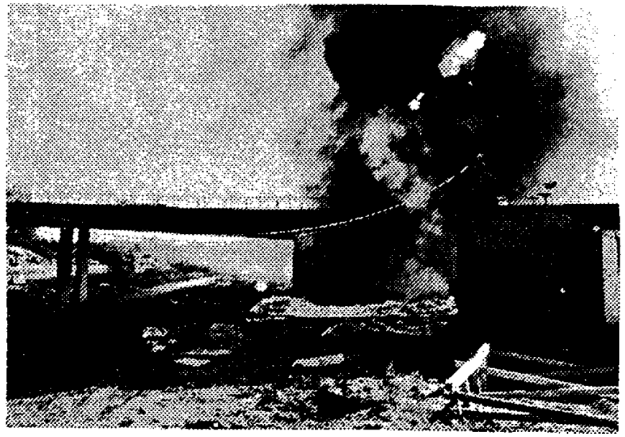
Note U.S. Federal Highways Administration will accept either method

SALT LAKE 2002

URS

AECOM

FLAMMABILITY CONSIDERATIONS



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

Fig. 34 Bridge abutment damaged by EPS blocks put on fire (NPRA)

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)

Statens vegvesen
Norwegian Public Roads Administration

FLAMMABILITY CONSIDERATIONS

Option 1 – Use Flame Retardant Additive

Fire Characteristics

- Limiting Oxygen Index: min. 24% per ASTM D2863. Airfoam's EPS for construction applications contains a polymeric (non-HBCD) fire retardant modifier.

Surface Burning Characteristics

- **Canada**: CAN/ULC-S102.2: Flame-Spread Rating ≤290, Smoke Developed Classification over 500.
- **USA**: ASTM E84 (UL 723)[a]: Flame Spread Index ≤25, Smoke-Developed Index ≤450 up to 6" thick.

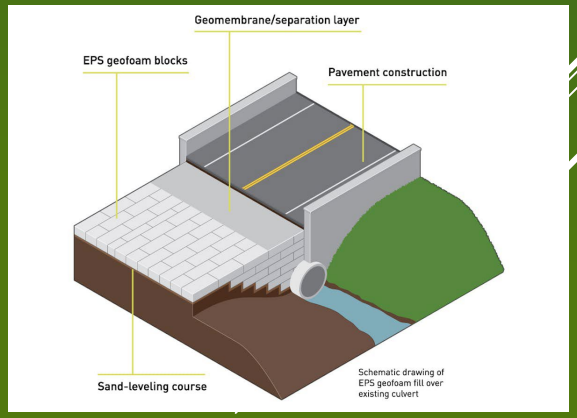
https://www.airfoam.com/geofoam/Geofoam-Technical-Summary.pdf

Option 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

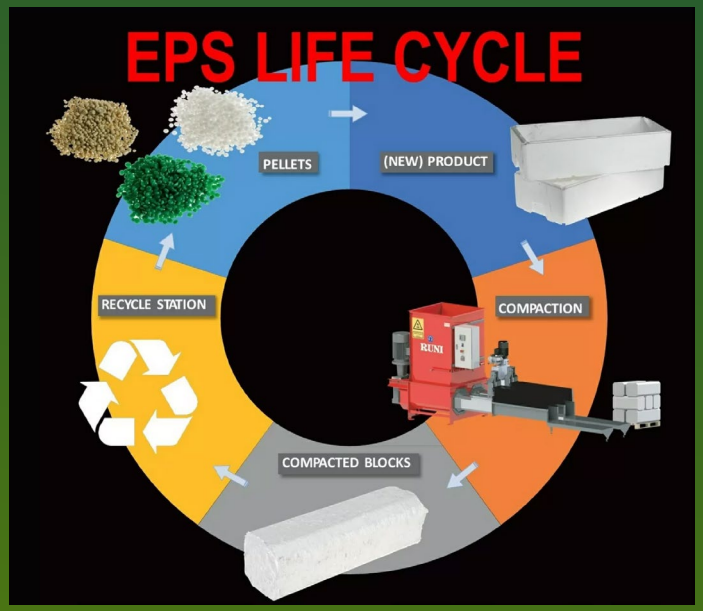
EPS Industry Alliance

Option 2 cont. – Cover or Incapsulate Block



SGA

REUSE AND RECYCLING



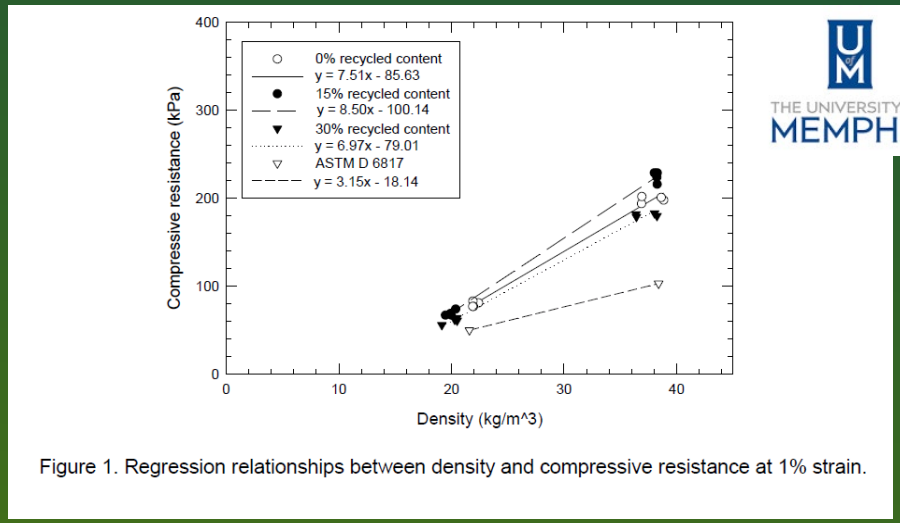


Figure 1. Regression relationships between density and compressive resistance at 1% strain.

THE UNIVERSITY OF MEMPHIS.

Recycled EPS-Comparable-to-Nonrecycled-EPS-Geofoam.pdf

Growing New Ideas

EPS Industry Alliance Geofoam Civil Engineering

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

Statens vegvesen
Norwegian Public Roads Administration

Fig. 35 **a** Stockpile of EPS from Løkkeberg Bridge. **b** Reuse of EPS blocks from Løkkeberg Bridge (NPRA)

https://5th-international-conference-on-geofoam-blocks-in-construction-a/15790828?tocPage=1

PARTNERS

Walt Disney
Oracle Group
Aerix Industries
Advanced Engineered Foam Solutions
Throop Lightweight Fill
HDR
PKS Since 1964
MEGA Packaging Corporation
UTA
UDOT Keeping Utah Moving
Statens vegvesen
Norwegian Public Roads Administration
AFM Corporation
SPL Supreme Petrochem Ltd

PORT OF SAN FRANCISCO

Lucas Museum of Narrative Art

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Oregon State
USGS science for a changing world
Utah Geological Survey
Bulletin
PEER
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Wadsworth Brothers
Earth Mechanics, Inc.
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City of Los Angeles Founded 1781
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Tishman Speyer

AECOM
IM
ISO Moulders
POLYMOLDING
JACOBSEN
Layton Constructing with Integrity
Bechtel
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Caltrans
WSDOT
IOWA DOT Smarter | Simpler | Customer Driven
State of Ohio Department of Transportation
Indiana Department of Transportation
INDOT
New York State
Syracuse
NMBU Norwegian University of Life Sciences

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:
ATKINS
ATLAS

Hydrotech

Mission Rock Residential

GeoFoam México
ACH Foam Technologies
Questar Gas
Broadway
Mountain-Plains Consortium
U.S. Department of Transportation
Federal Highway Administration
Imagine U
The University of Memphis
Insulfoam
Cell-Crete
Kiewit
Polioles
EPS Industry Alliance
EPSDER
EPS Sanayi Dernegi
Turkish EPS Industry Association
EUMEPS
Stacy and Witbeck

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

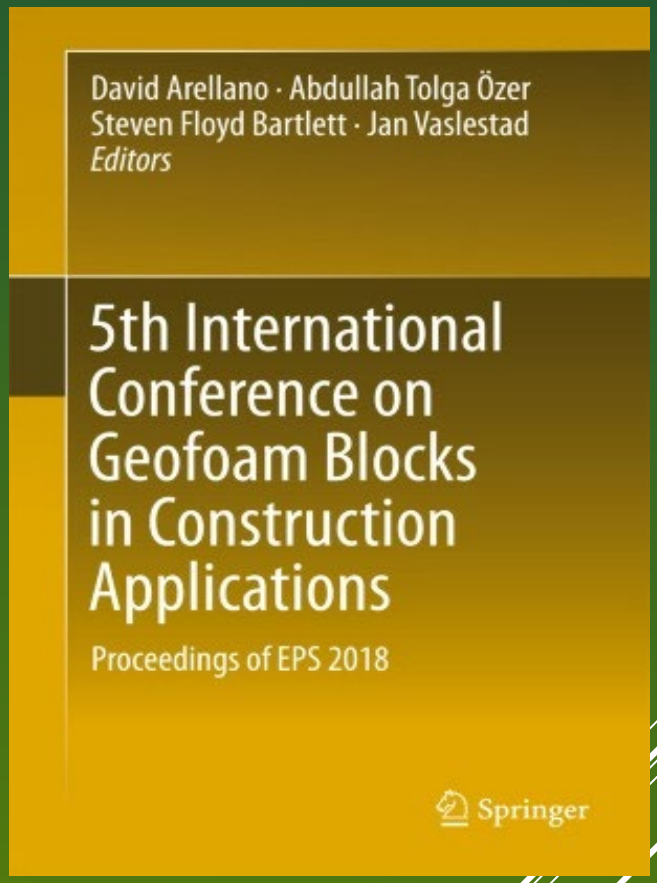
ASCE 2010 Local Outstanding Civil Engineering Achievement Awards, Geotechnical Category – Outstanding Award SR 519 / I-90 to SR 99, Intermodal Access I/C Improvements Phase 2 Design Build Project Seattle, Washington

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

RESOURCES

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

Authors: Stark, Bartlett and Arellano, 2012



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