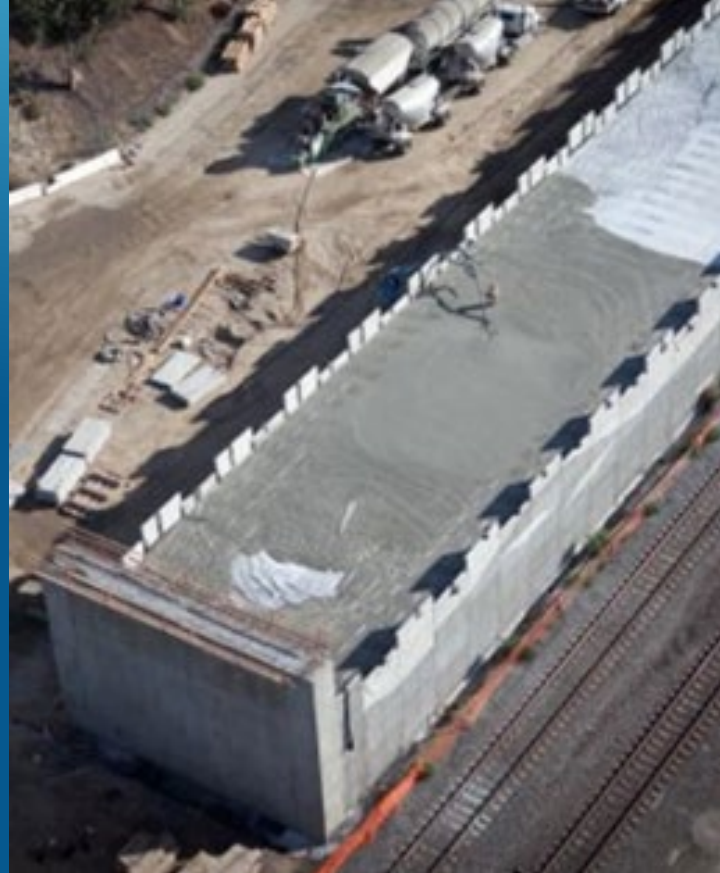
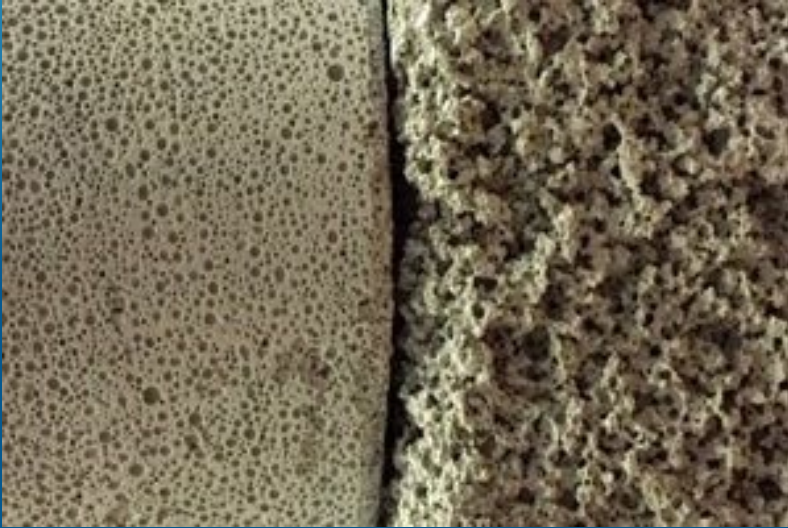


APPLICATION OF LIGHTWEIGHT FILLS IN CIVIL AND TRANSPORTATION ENGINEERING



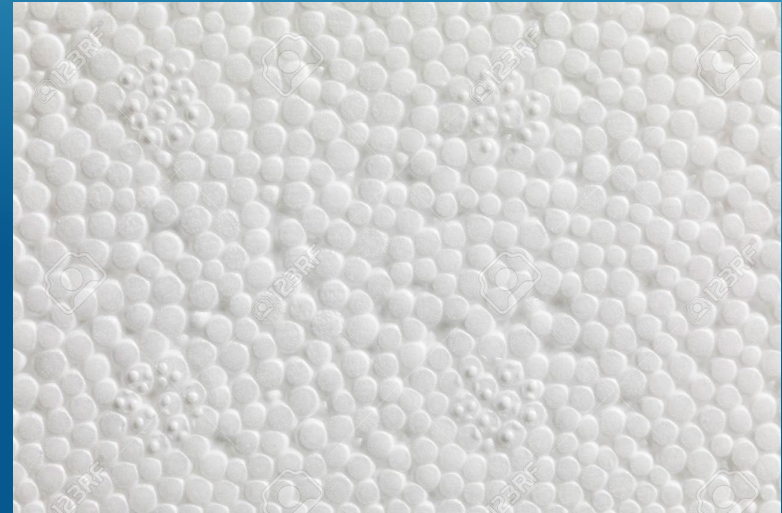
Steven F. Bartlett, Ph.D. P.E
Associate Chair
Department of Civil and Environmental
University of Utah

LIGHT-WEIGHT MATERIALS



Light-Weight Cellular Concrete

Impermeable (left) (LCC)
Permeable (right) (PLCC)
High porosity 60 to 70 percent
Permeability = c. sand to f. gravel
Unit weight 25 to 30 pcf



Expanded Polystyrene (Geofoam)

Impermeable – but can have flow through joints
Unit weight 1.25 to 1.5 pcf (for most applications)
Compressible under concentrated loads
Can undergo creep strain if over-stressed

PROPERTIES AND FUNCTION OF LIGHT-WEIGHT MATERIALS

Properties

- Light-weight to ultra light-weight
- High strength to mass ratio

Important Functions

- Reduces settlement
- Improves bearing capacity
- Improves foundation and slope stability
- Decreases horizontal and vertical loads
- Rapid construction
- Can saves construction time and money

INTRODUCTION TO EPS MANUFACTURING AND PROPERTIES



raw styrene beads

steam expanded
(1st steam heating)

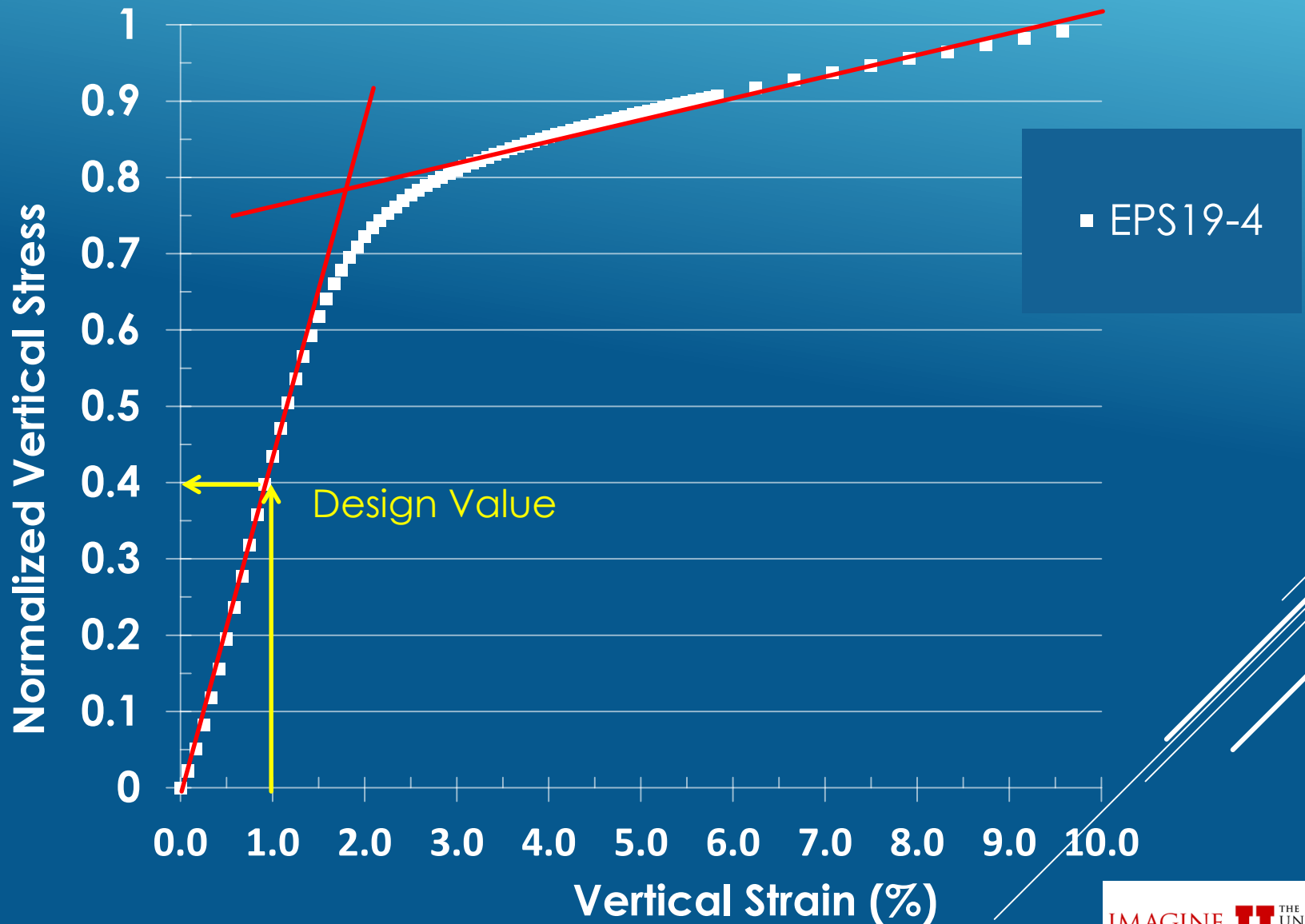


block molding (2nd steam heating)



block placement

COMPRESSIVE RESISTANCE



EASE OF PLACEMENT AND CONSTRUCTION



Geofoam Placement
photo courtesy of
BASF- Kuala Lumpur,
Malaysia

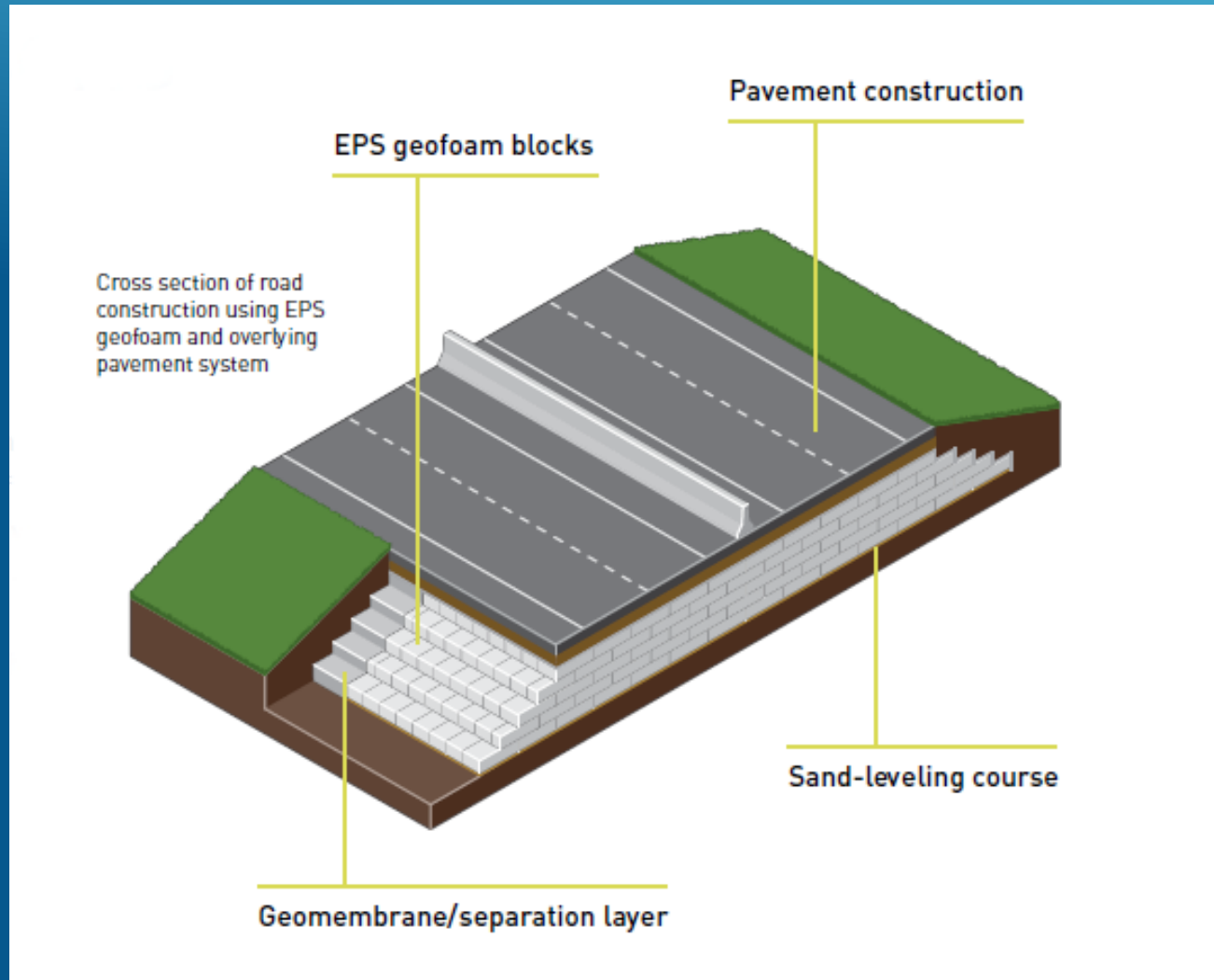


Cellular Concrete Placement
photo courtesy of Aerix Industries

SELECTED TOPICS

- Roadway construction over soft soils / reclaimed land
- Bridge abutments and under fill
- Accelerated bridge construction
- Retaining and buried wall backfill
- Culverts, pipelines and buried structures
- Rail embankment
- Slope stabilization
- Landscaping and vegetative green roofs

ROADWAY CONSTRUCTION OVER SOFT SOILS / RECLAIMED LAND



ROAD CONSTRUCTION OVER POOR SOILS

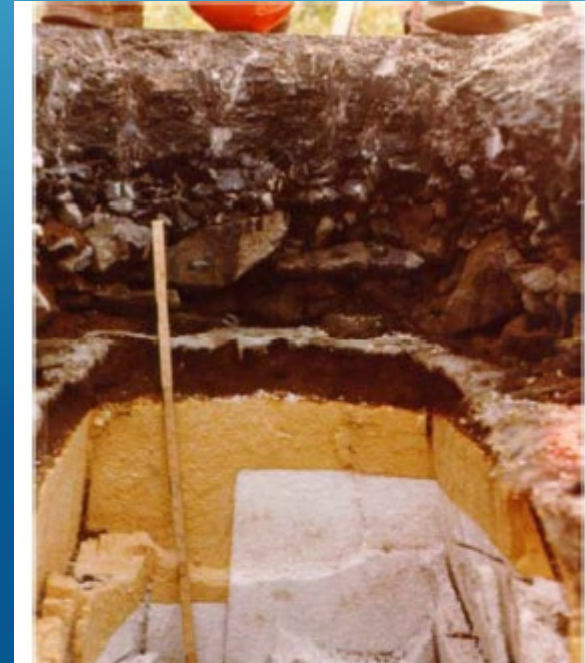
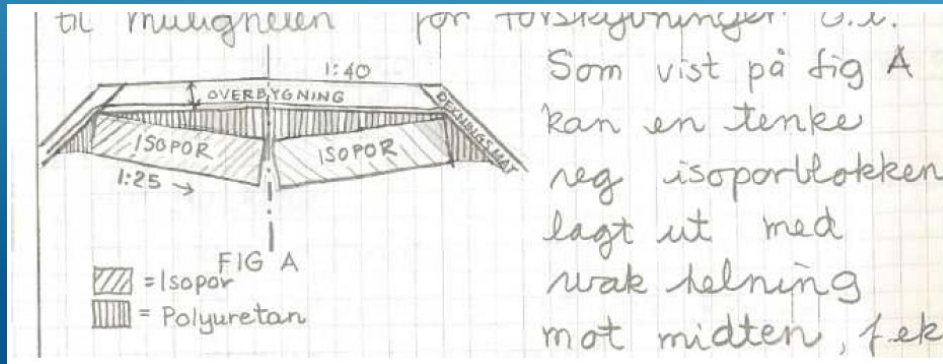


Figure 3. Excavation of the first EPS embankment at Flom bridge (EPS and polyurethane as protective layer).

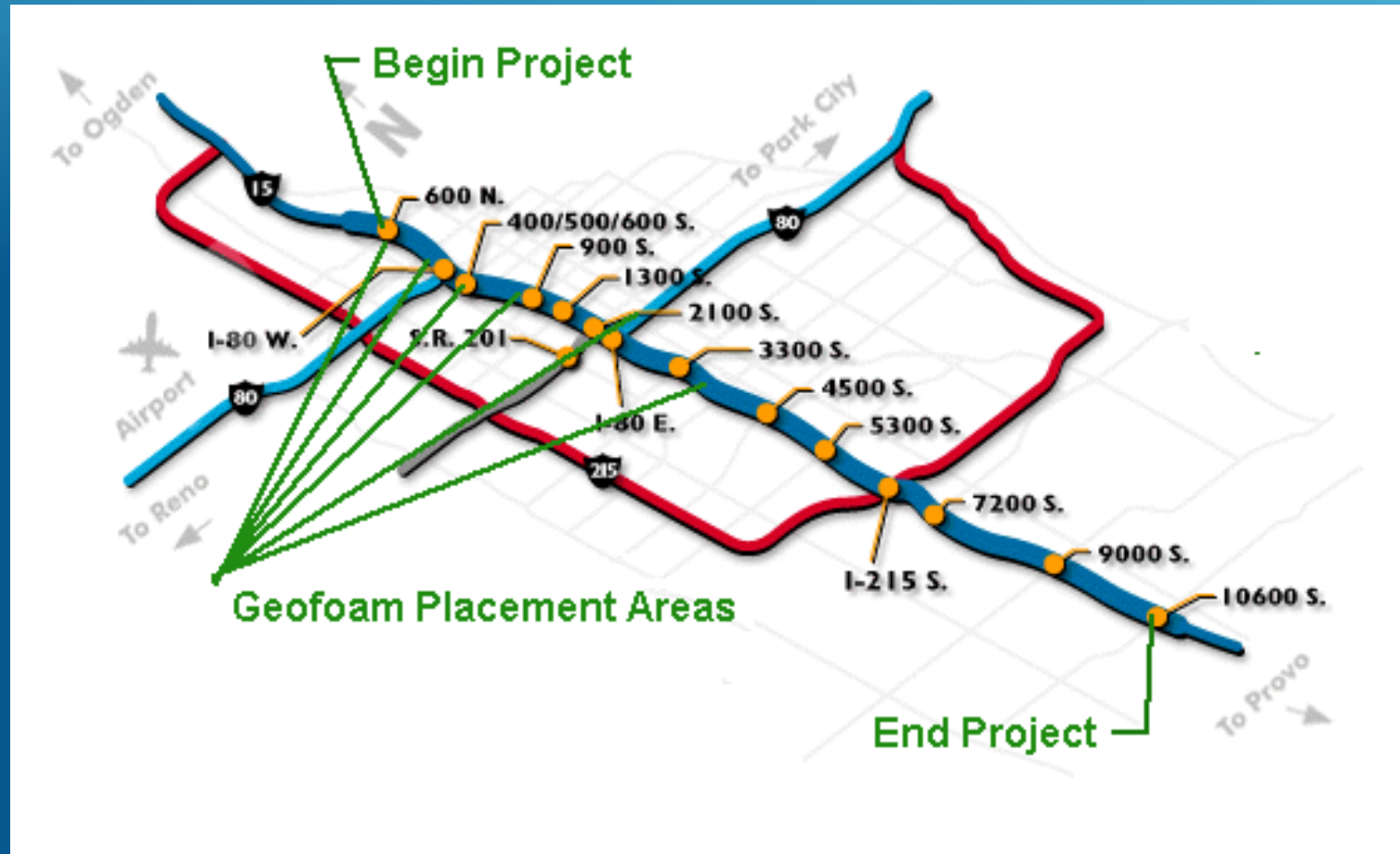


Flom Bridge – 1972 – Lillestrom, Norway

2002 HOST CITY OF WINTER OLYMPICS – SALT LAKE CITY

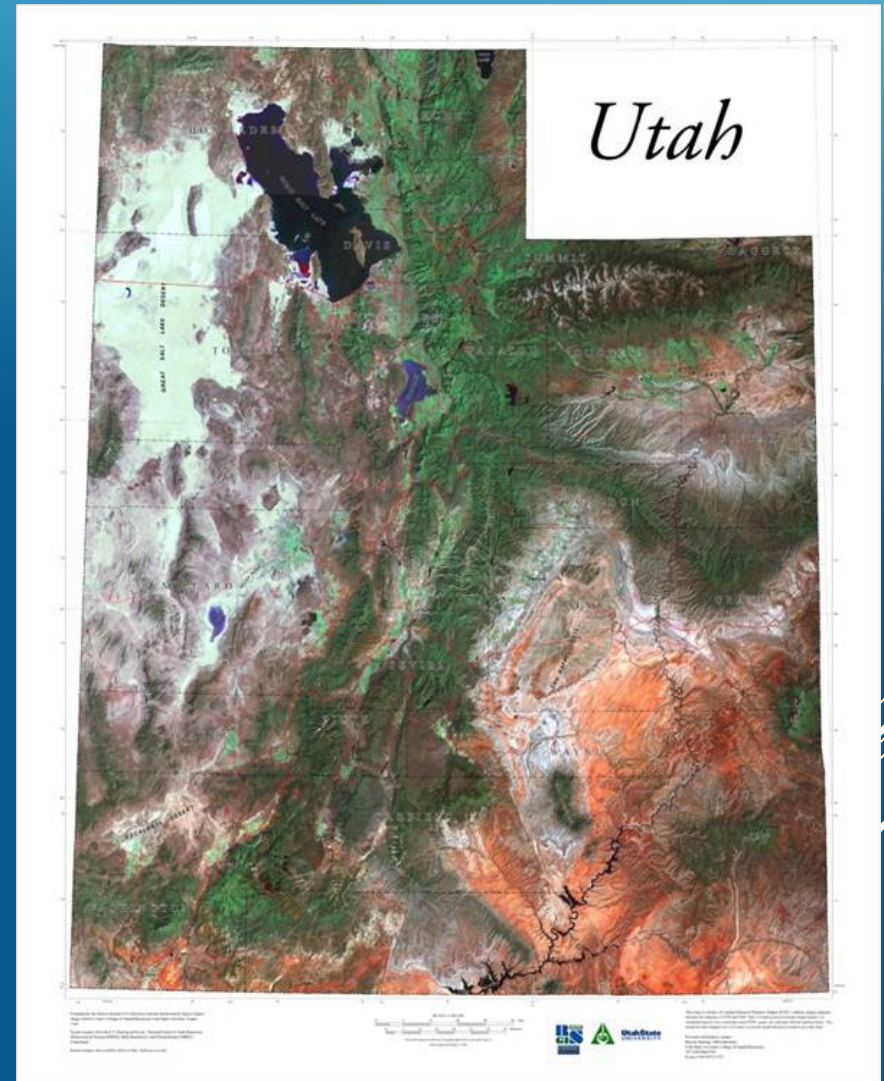
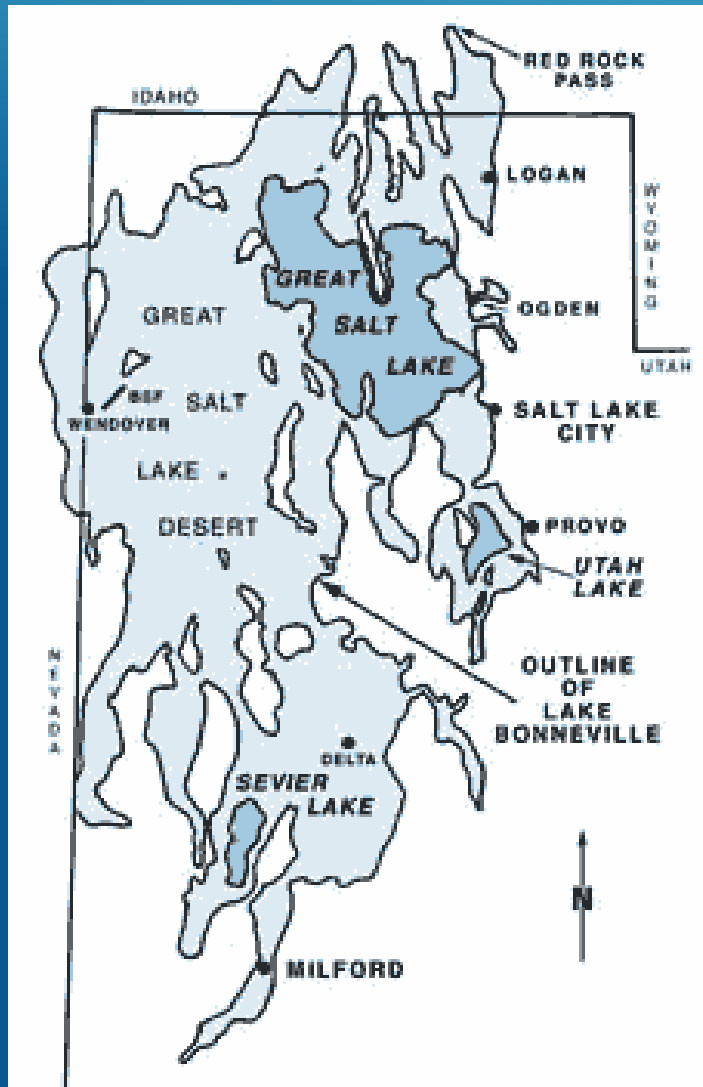


ROADWAY CONSTRUCTION OVER SOFT SOILS I-15 PROJECT (ROAD WIDENING)

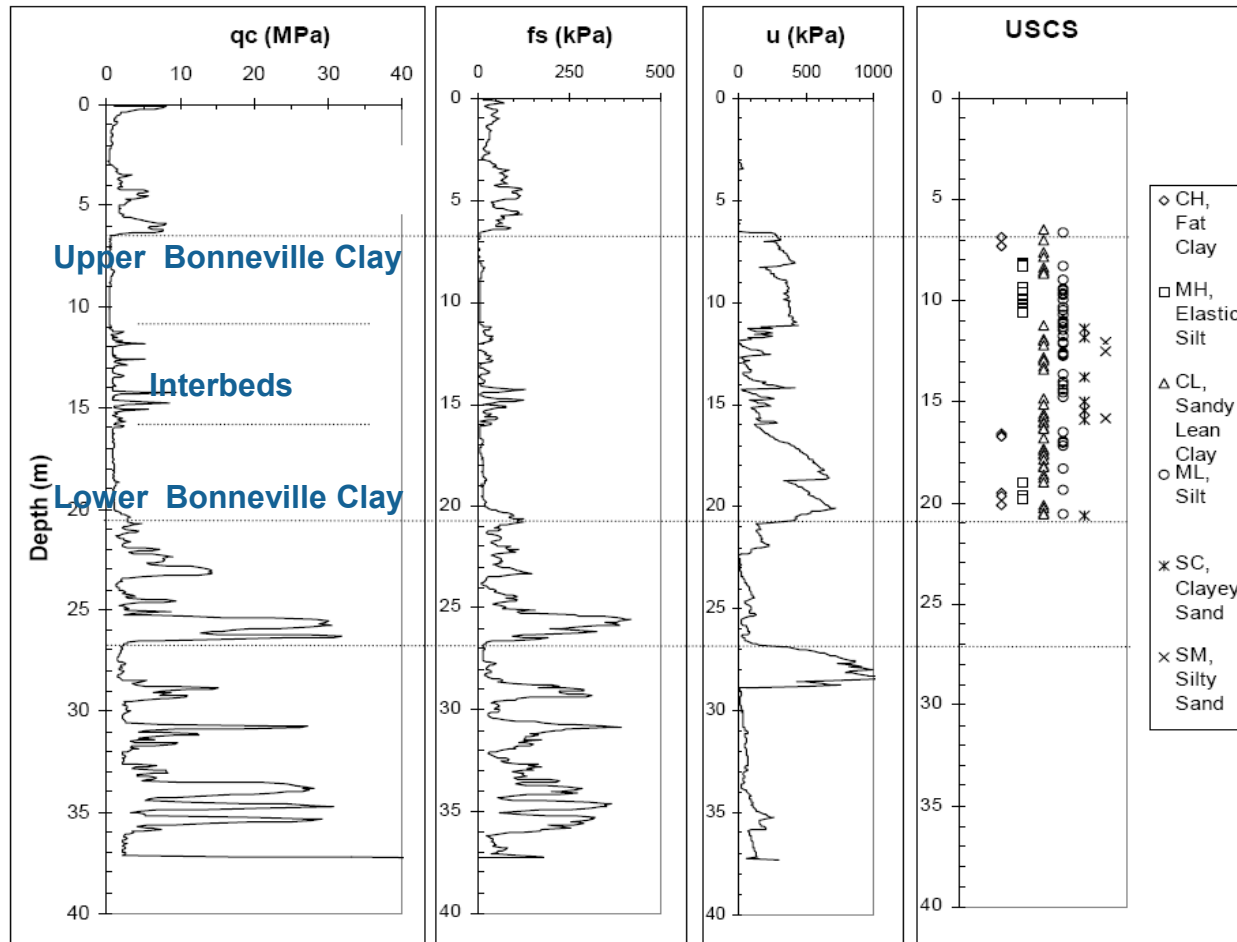


Approx. 100,000 cubic meters of geofoam was placed.
World's largest geofoam project.

PLEISTOCENE LAKE BONNEVILLE IN UTAH

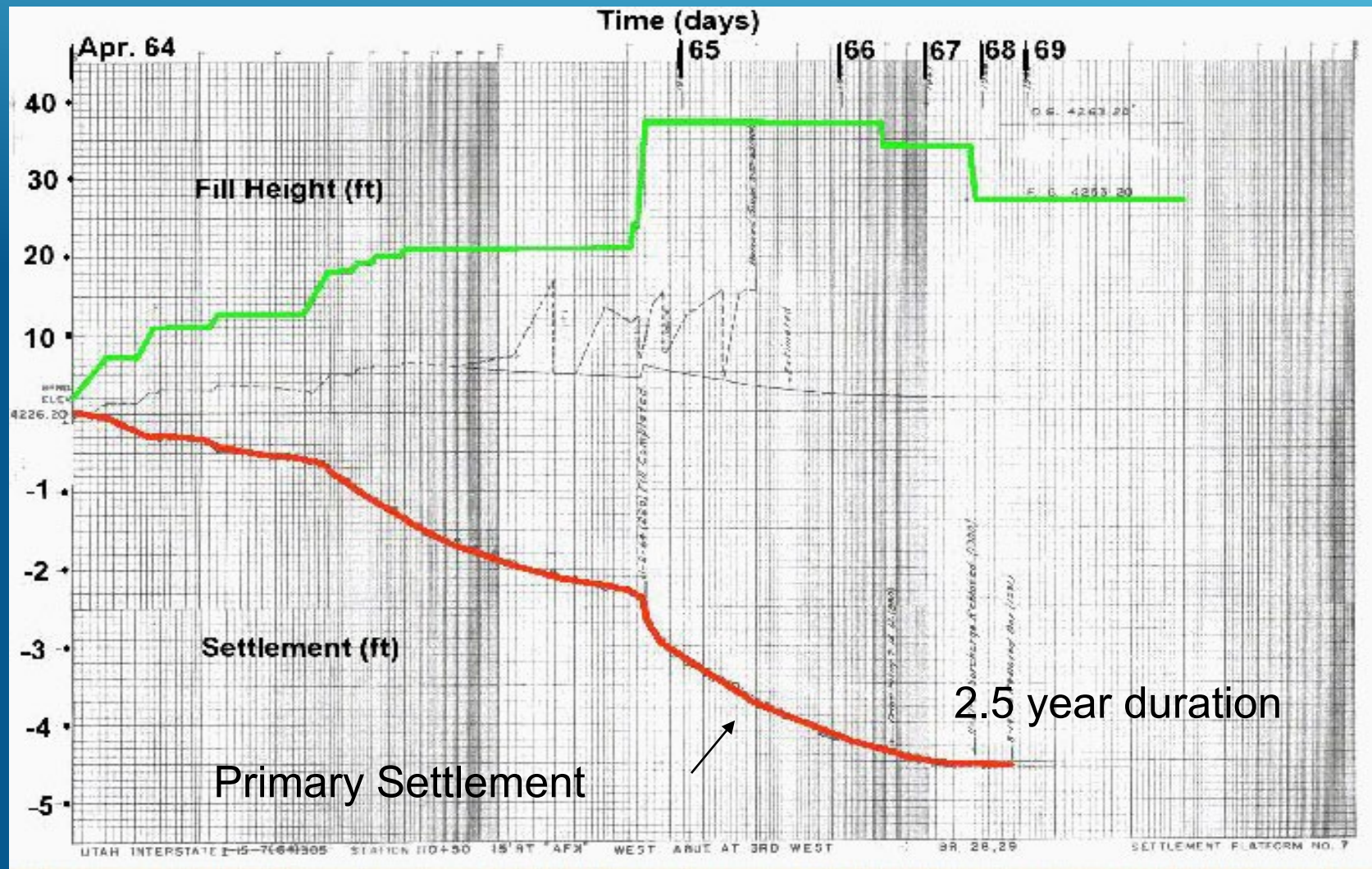


I-15 RECONSTRUCTION PROJECT

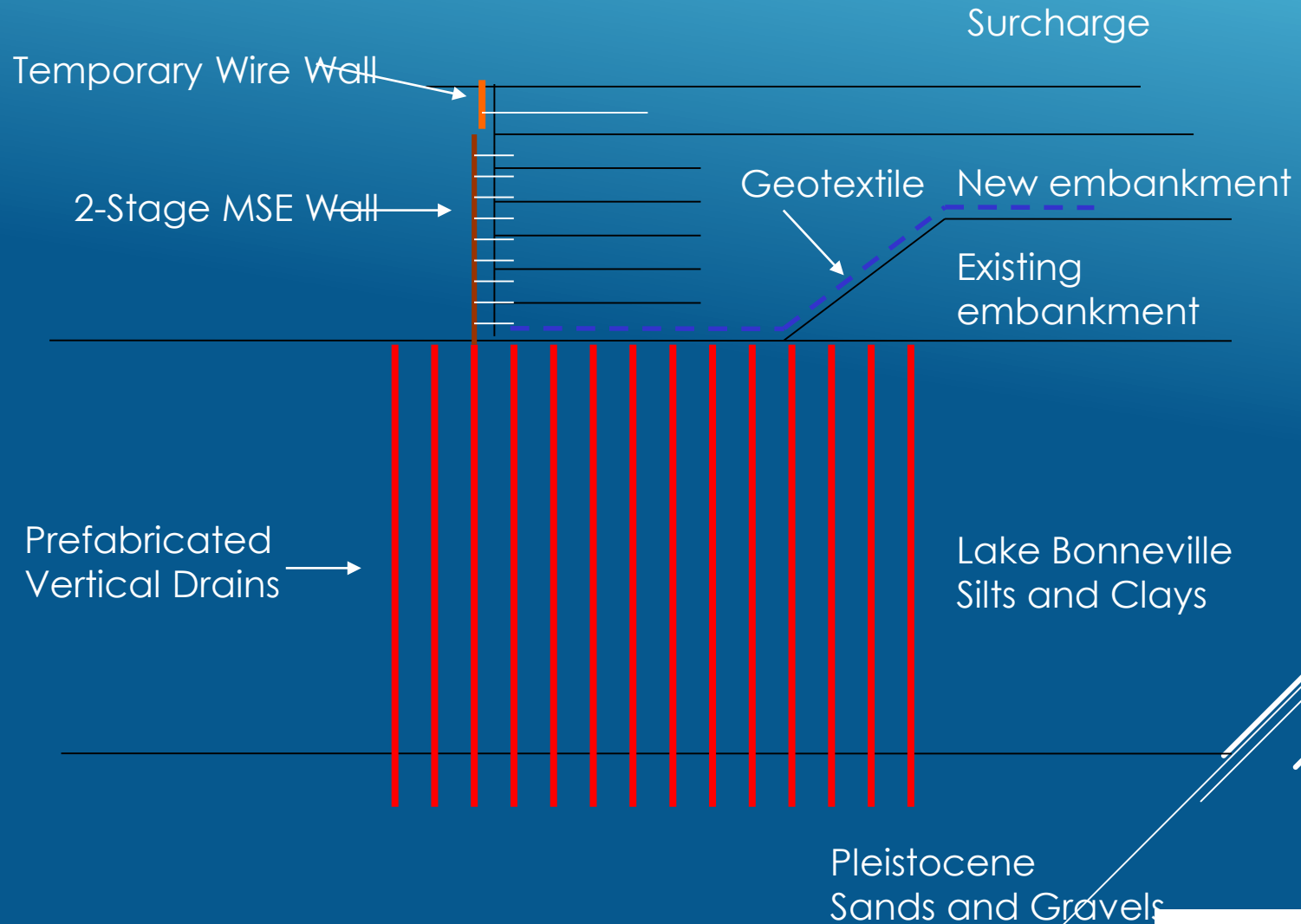


Subsurface Profile in Salt Lake Valley

I-15 PROJECT – SETTLEMENT RECORD 1960s



TYPICAL I-15 EMBANKMENT CONSTRUCTION



CONVENTIONAL I-15 EMBANKMENT CONSTRUCTION



PV or Wick Drains

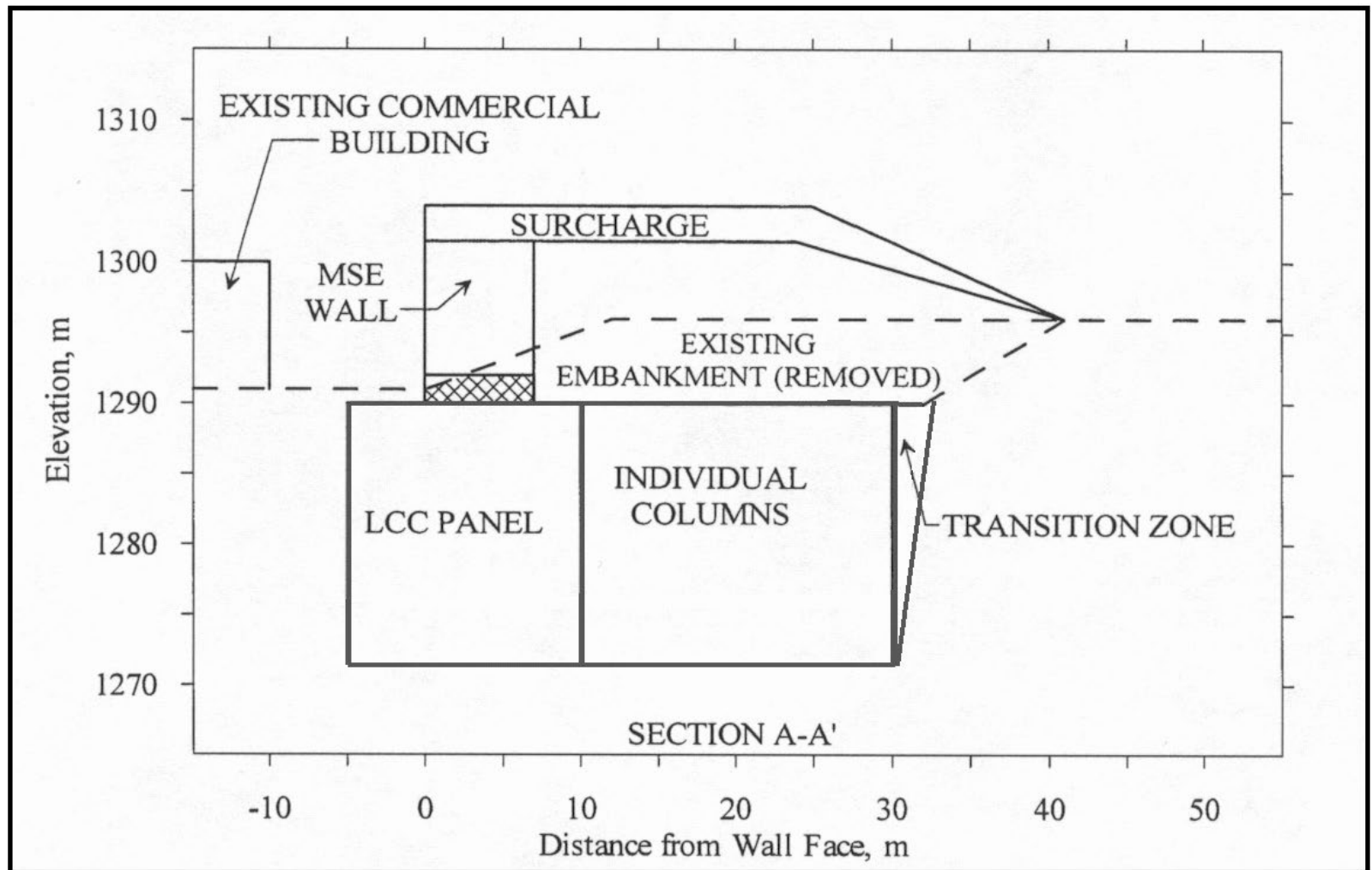


Surcharging



Geotextile Reinforced Slopes

LIME CEMENT COLUMNS



LCC = Lime Cement Columns

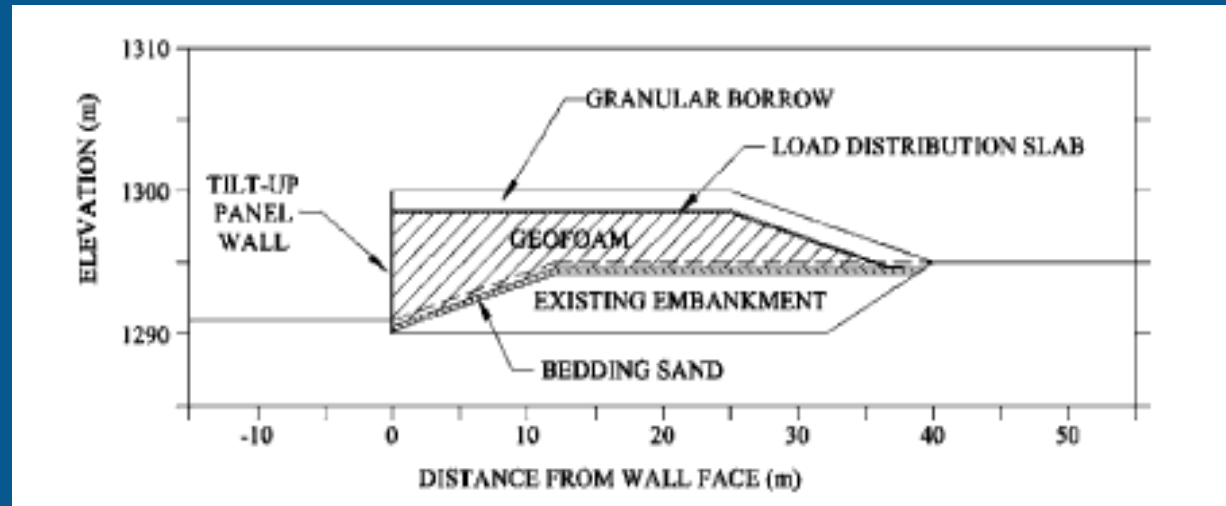
LIME CEMENT COLUMNS (CONT.)



Lime Cement Columns

One stage MSE atop columns

I-15 RECONSTRUCTION PROJECT – TYPICAL GEOFOAM FILL



I-15
Reconstruction
Project
Salt Lake City,
Utah

I-15 RECONSTRUCTION PROJECT – GEOFOAM FILL AERIAL VIEW



I-15 Reconstruction Project, Salt Lake City, Utah

I-15 RECONSTRUCTION PROJECT

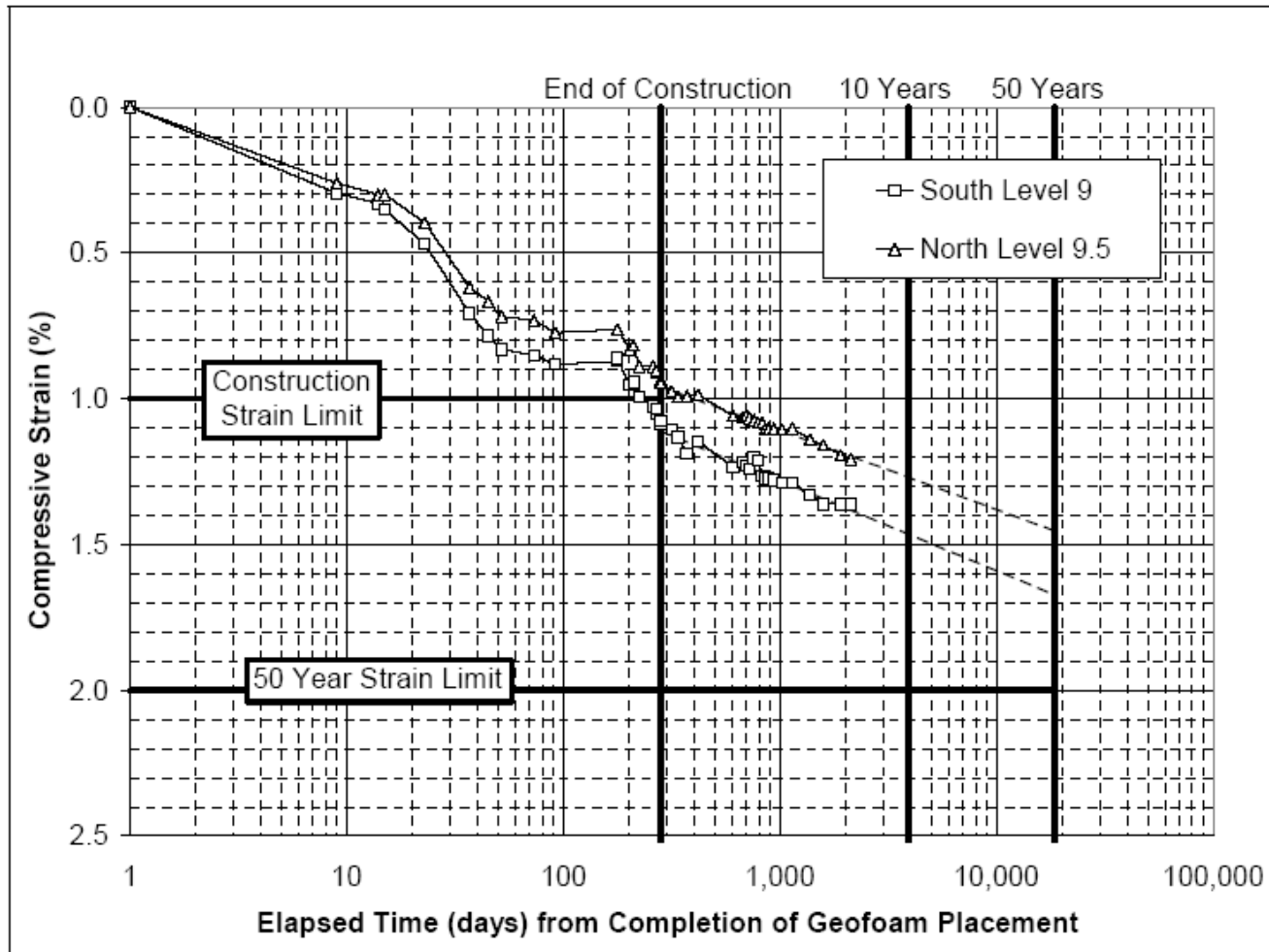


Reinforced Concrete
Load Distribution Slab



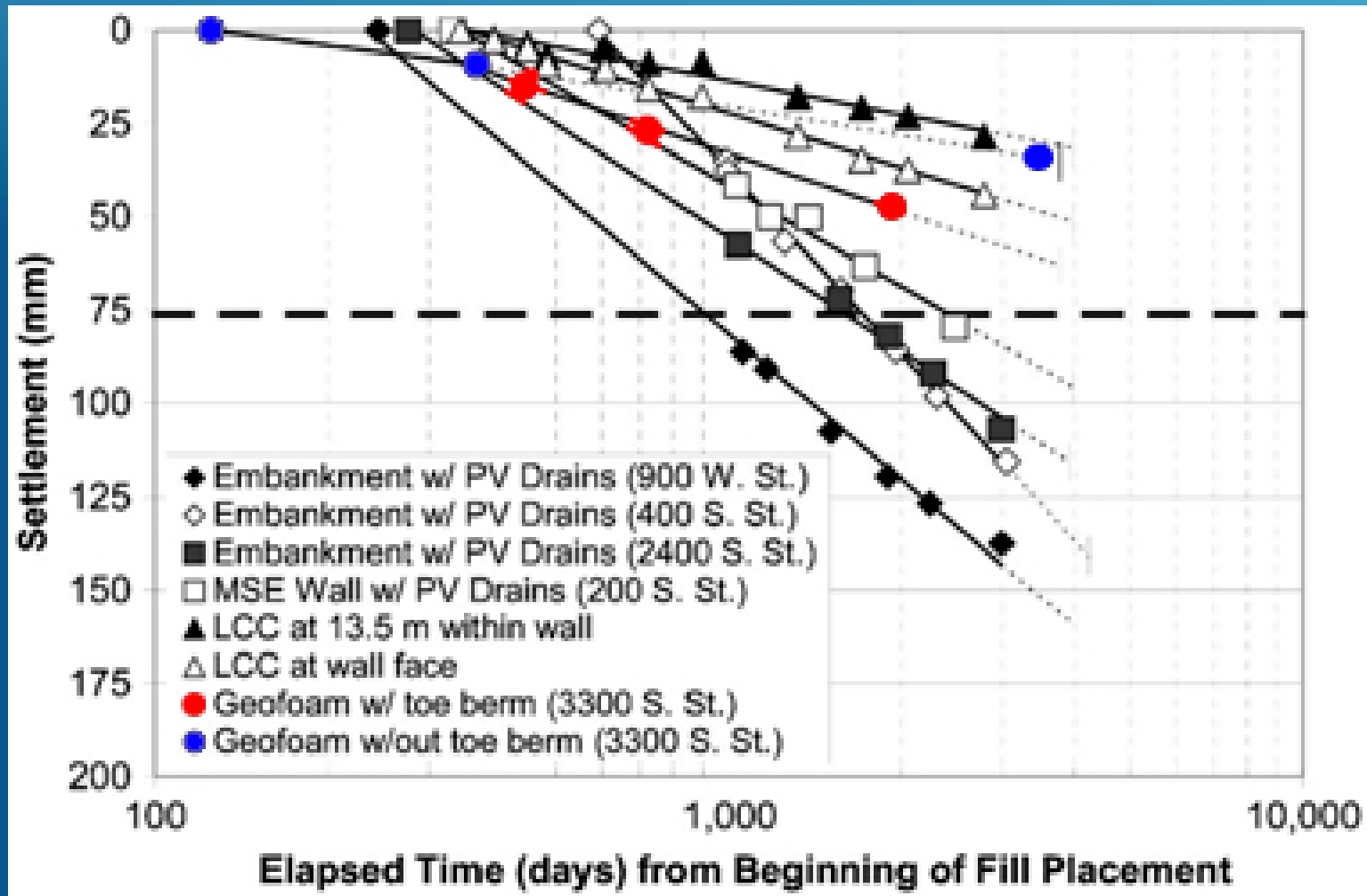
Completed Load Distribution Slab

SETTLEMENT MONITORING 100 SOUTH STREET GEOFOAM EMBANKMENT



1% elastic construction strain

GEOTECHNOLOGY SETTLEMENT PERFORMANCE I-15 RECONSTRUCTION



I-15 GEOFOAM CONCLUSIONS

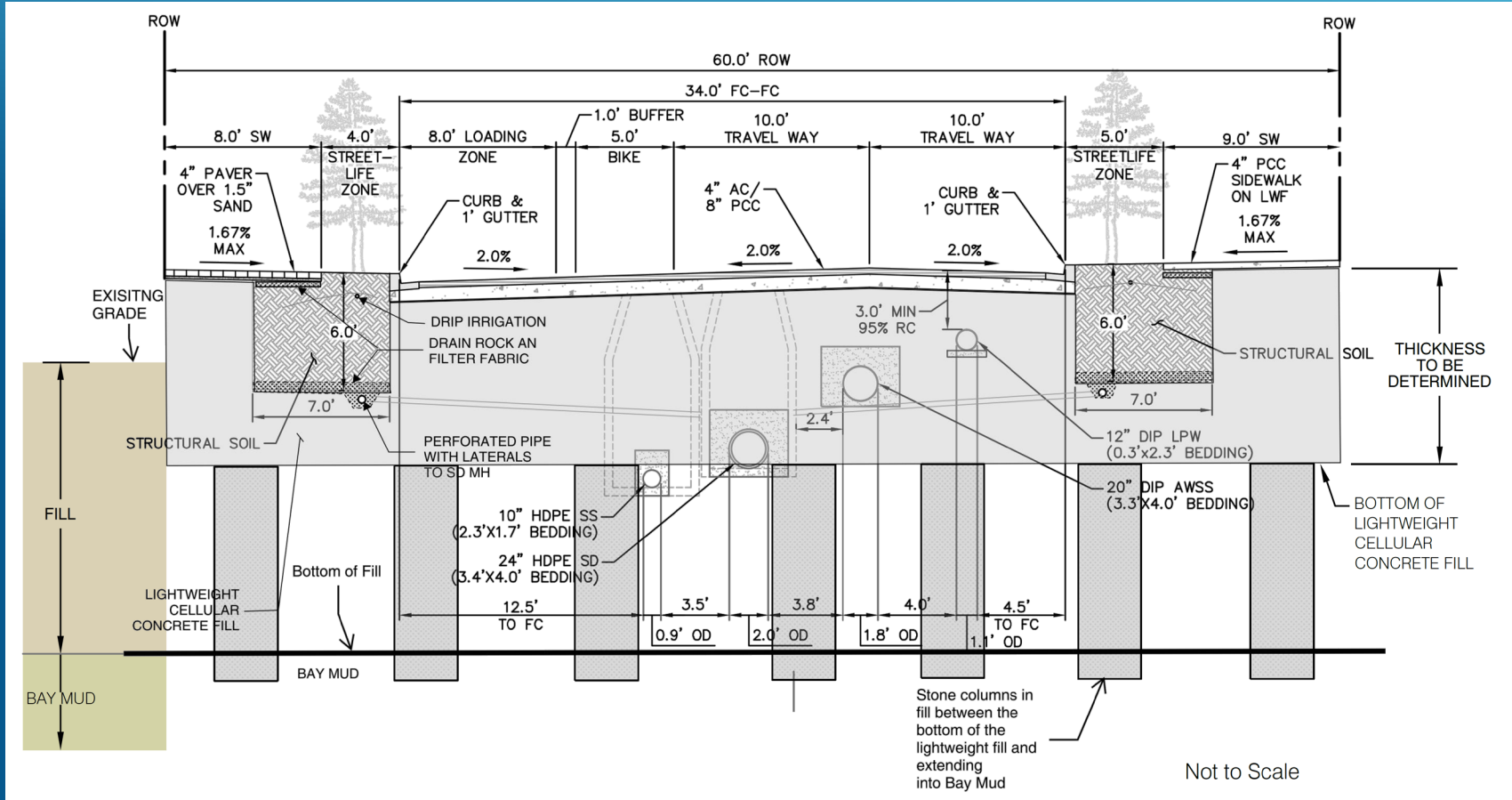
1. Geofoam fills performed as expected with no major issues.
2. Approximately 1 percent vertical strain occurred during construction.
 - a. Strain due to seating and compression of geofoam.
3. Approximately 0.3 to 0.5 percent creep strain (15 mm) has occurred in a 10-year post construction period.
4. The vertical stress distribution that develops in a geofoam wedge fill is complex, but generally diminishes with depth.
5. Pressure cell measurements suggest that approximately 45 kPa of vertical stress has developed in the center of the geofoam mass. This is approximately 50 percent of the compressive strength of the geofoam.

CONSTRUCTION OVER RECLAIMED LAND



Reclaimed Land – Mission Rock Project, Port of San Francisco

ROADWAY X-SECTION MISSION ROCK



Mission Rock Development, San Francisco, CA.

ROADWAY CONSTRUCTION OVER RECLAIMED LAND

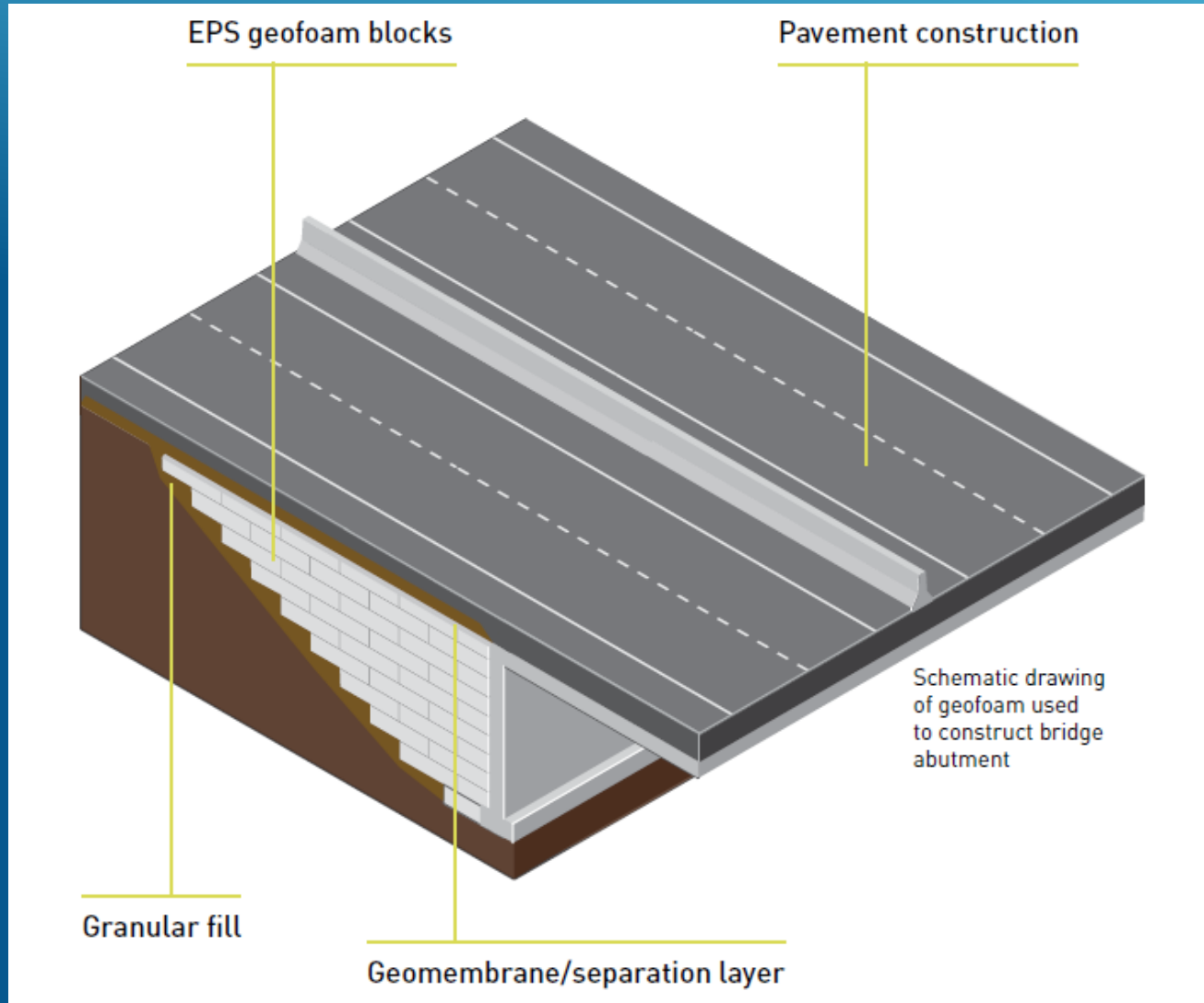


St. Rosa Road

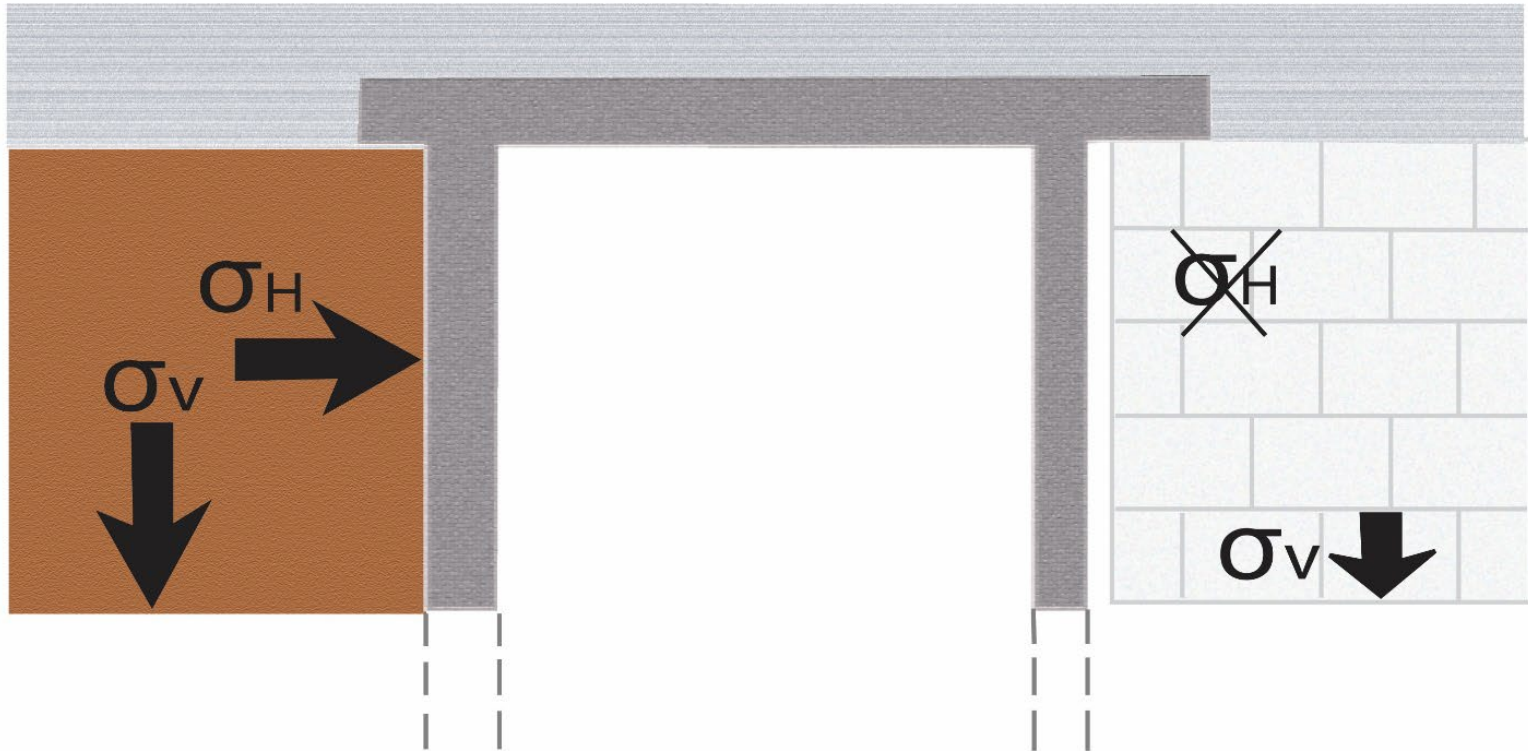
Private Road
Constructed Over
Rice Fields

St. Rosa, Philippines

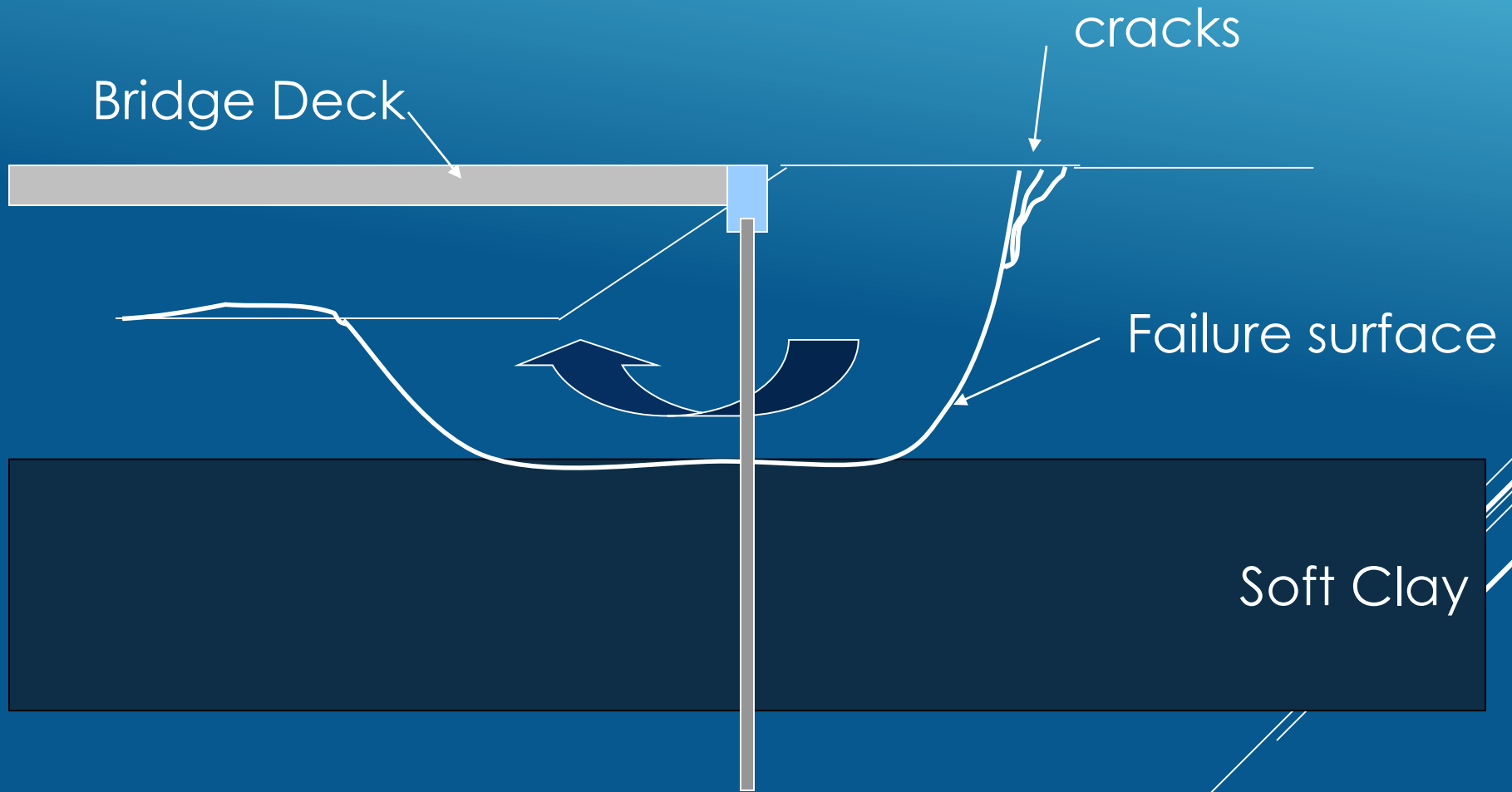
BRIDGE ABUTMENTS AND UNDER FILL



BRIDGE ABUTMENTS AND UNDER FILL



BRIDGE ABUTMENTS AND UNDER FILL IMPROVE EMBANKMENT STABILITY



BRIDGE ABUTMENTS AND UNDER FILL



I-15 Reconstruction,
Salt Lake City, Utah



Overpass, 5300 S. over
UTA TRAX
Salt Lake City, Utah

BRIDGE ABUTMENTS AND UNDER FILL

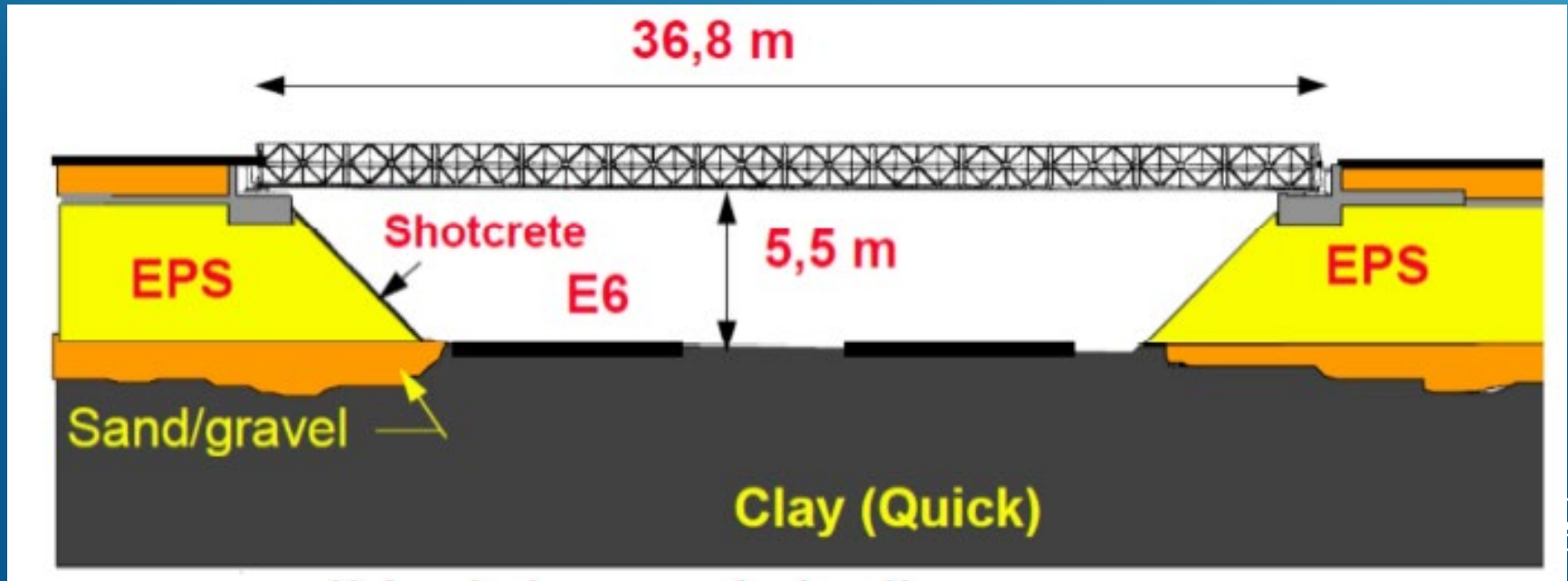


I-215 at 3300 South,
Salt Lake City, Utah



Tunnel Infill, Tucker Blvd.,
St. Louis, Missouri

ACCELERATED BRIDGE CONSTRUCTION (ABC)



Lokkeberg Bridge, Norway

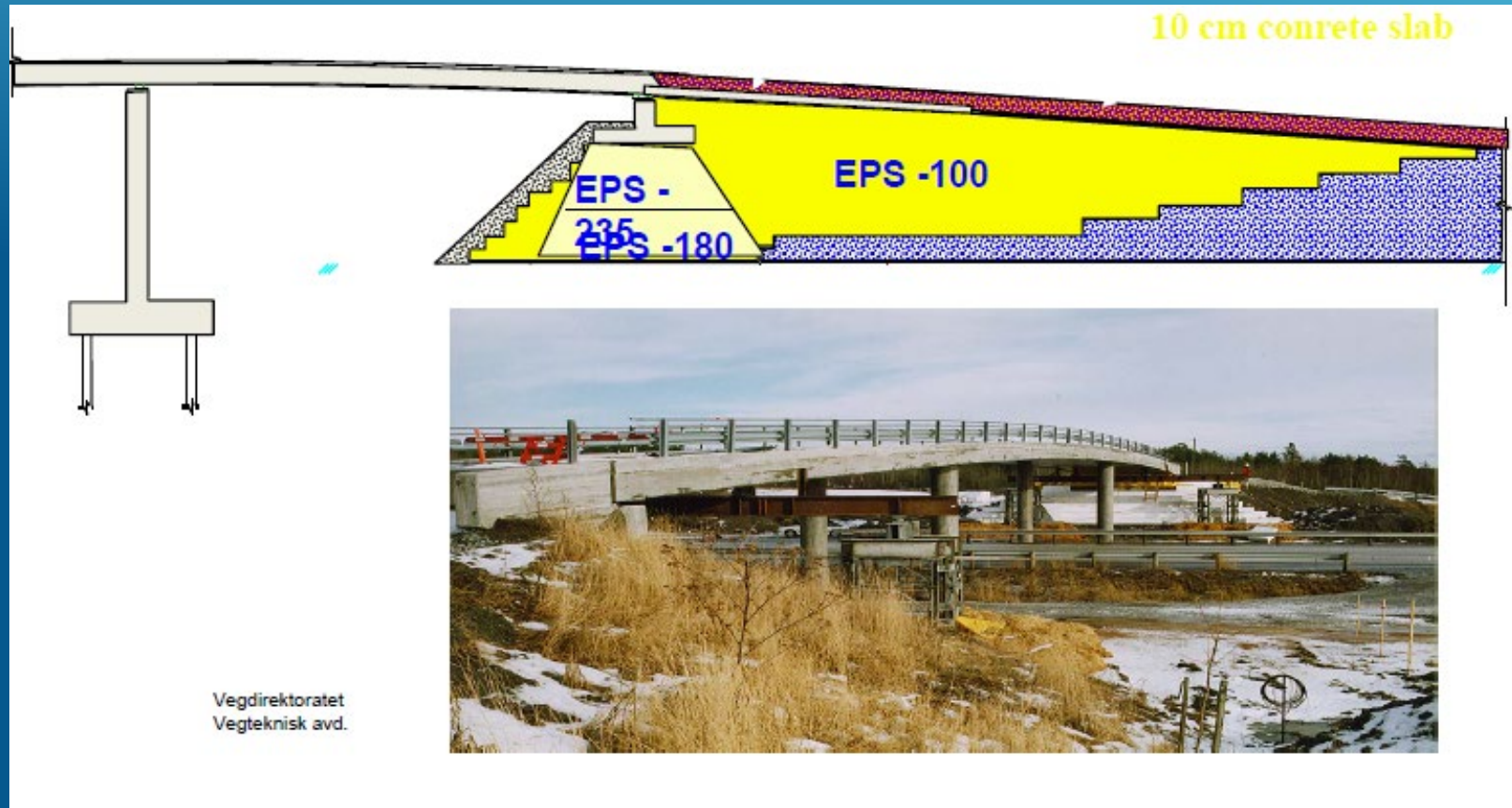
ACCELERATED BRIDGE CONSTRUCTION



Lokkeberg Bridge,
Norway

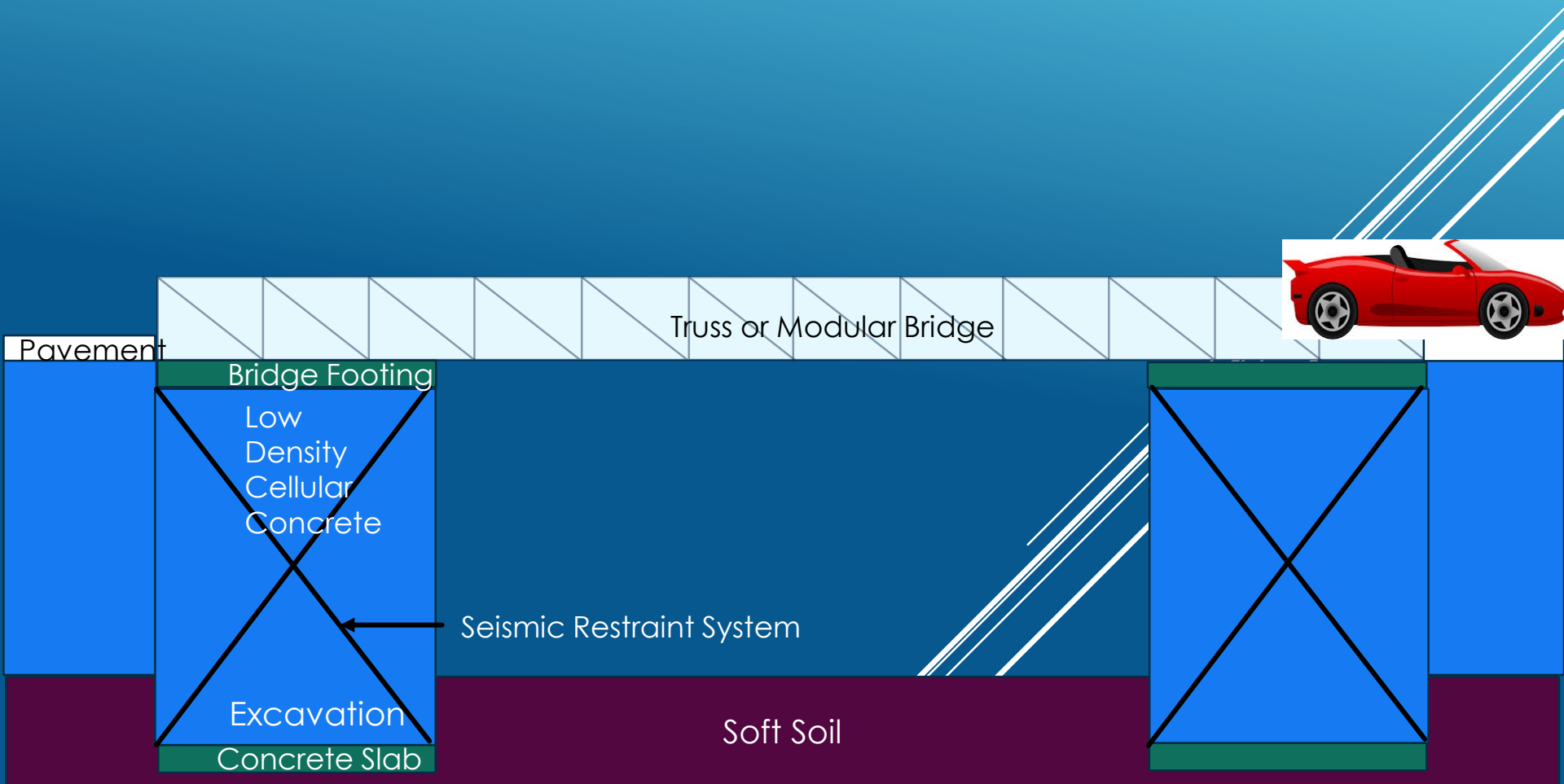


ACCELERATED BRIDGE REPAIR

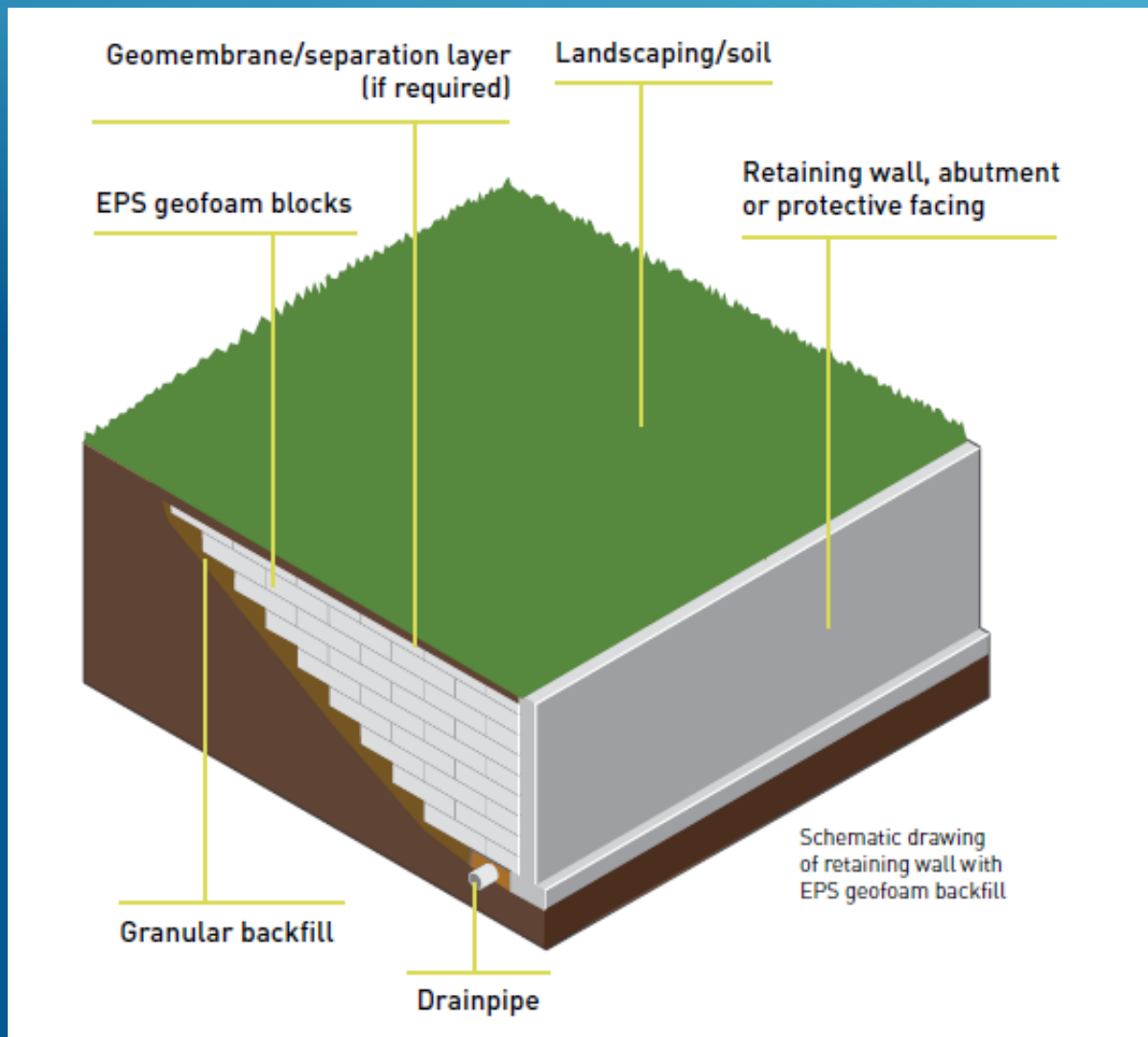


Hjelmungen Bridge,
Norway

ACCELERATION BRIDGE CONSTRUCTION WITH LOW DENSITY CELLULAR CONCRETE



RETAINING AND BURIED WALL BACKFILL



RETAINING AND BURIED WALL BACKFILL



Federal Courthouse – Salt Lake City

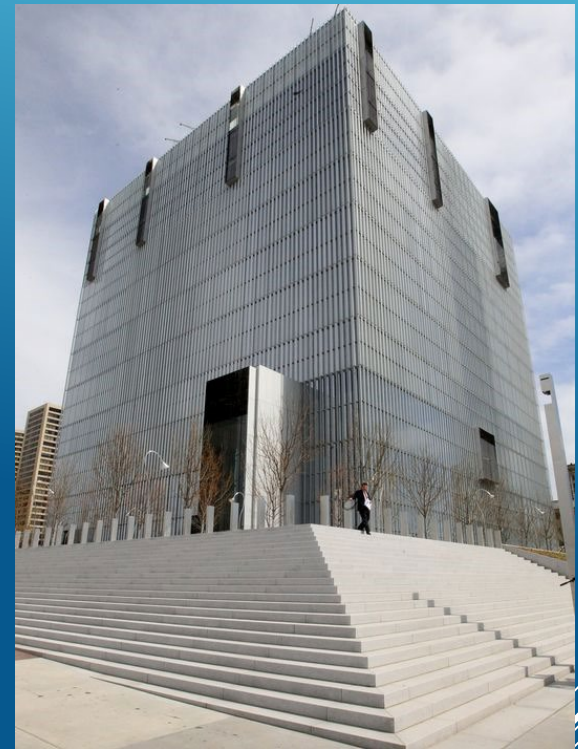


IHC Hospital – Murray, Ut



Casino/Hotel – Reidoso, NM

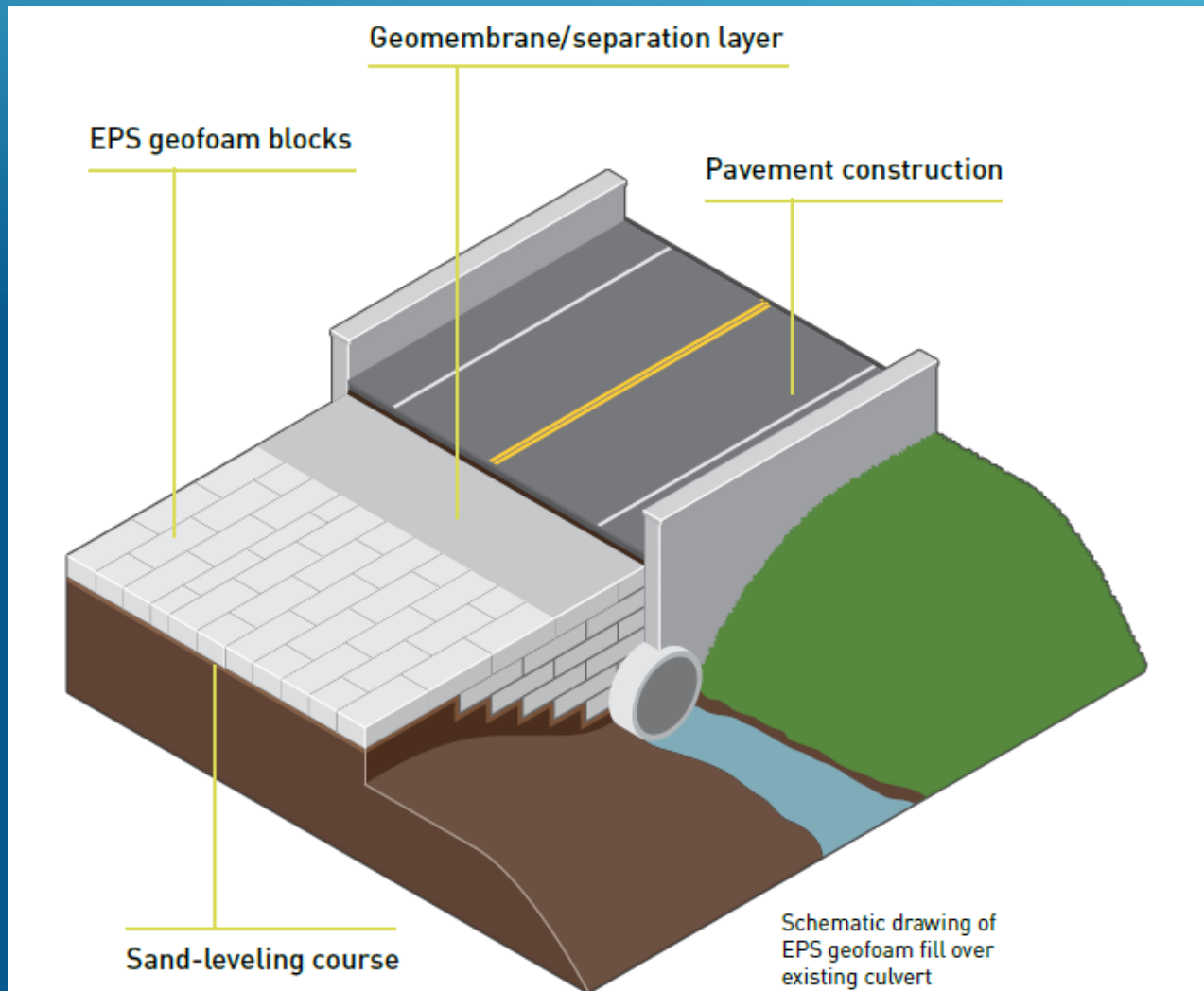
U.S. FEDERAL COURTHOUSE, SALT LAKE CITY, UTAH



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



CULVERTS, PIPELINES AND BURIED STRUCTURES



CULVERTS, PIPELINES AND BURIED STRUCTURES

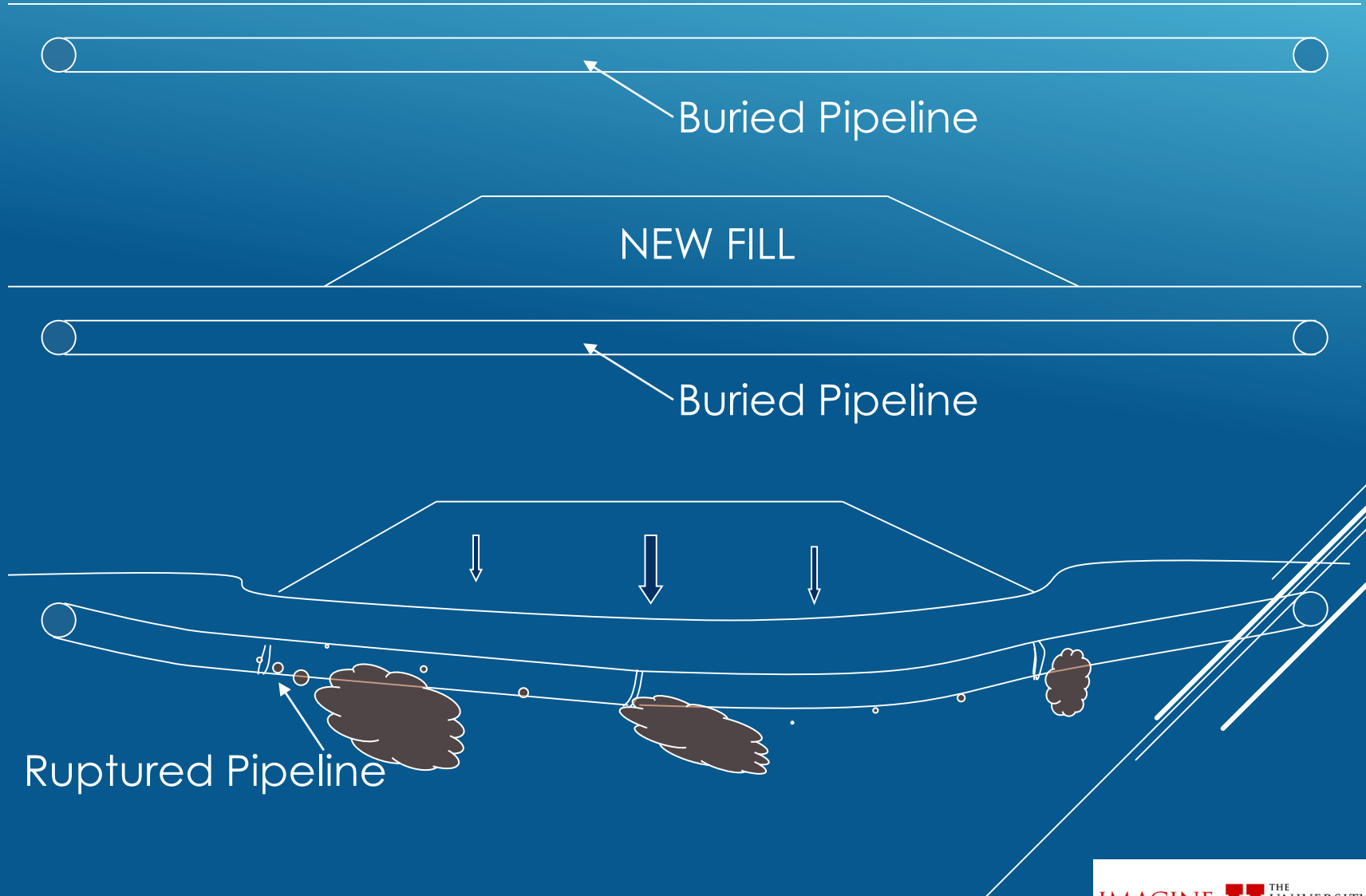


UTA Commuter Rail Widening Over Existing Culvert, Corner Canyon, Draper, Utah



Unknown location

CULVERTS, PIPELINES AND BURIED STRUCTURES



WASATCH FAULT AT LITTLE COTTONWOOD CANYON



NORMAL FAULT OFFSET – TYPICAL EXAMPLES



CULVERTS, PIPELINES AND BURIED STRUCTURES



Fire from rupture of high pressure gas line, North Ridge California Earthquake



Culverts, pipelines and buried structures



Alaskan Pipeline – Strike Slip Fault

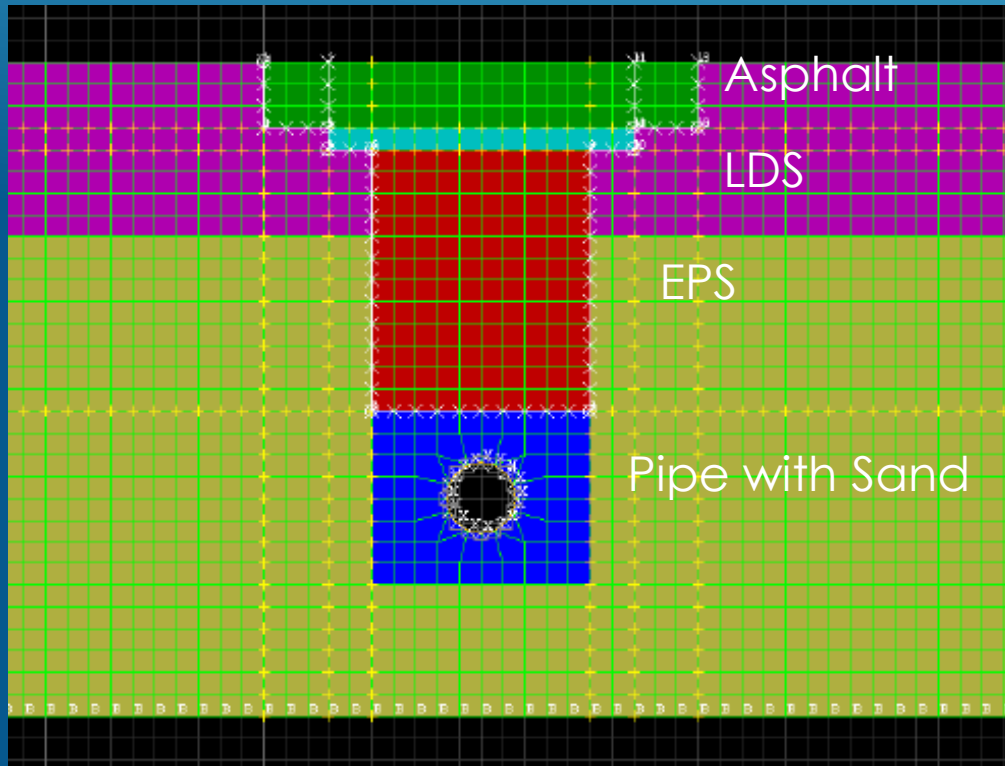


Alaskan Pipeline – Normal Fault

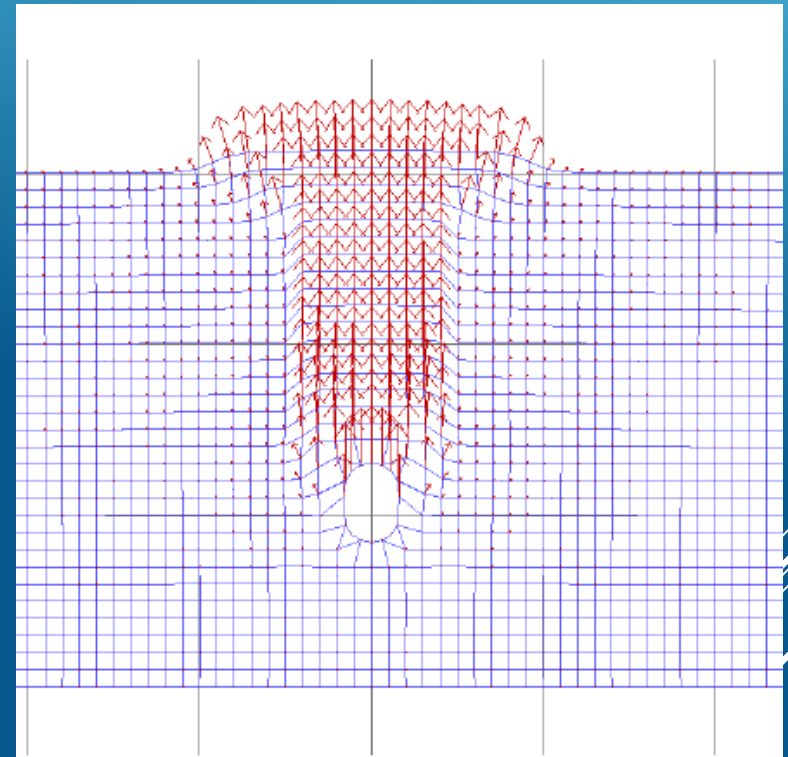
**PIPELINES (LIGHT-WEIGHT COVER
OVER FAULTS)**

CULVERTS, PIPELINES AND BURIED STRUCTURES

PIPELINES (LIGHT-WEIGHT COVER OVER FAULTS)

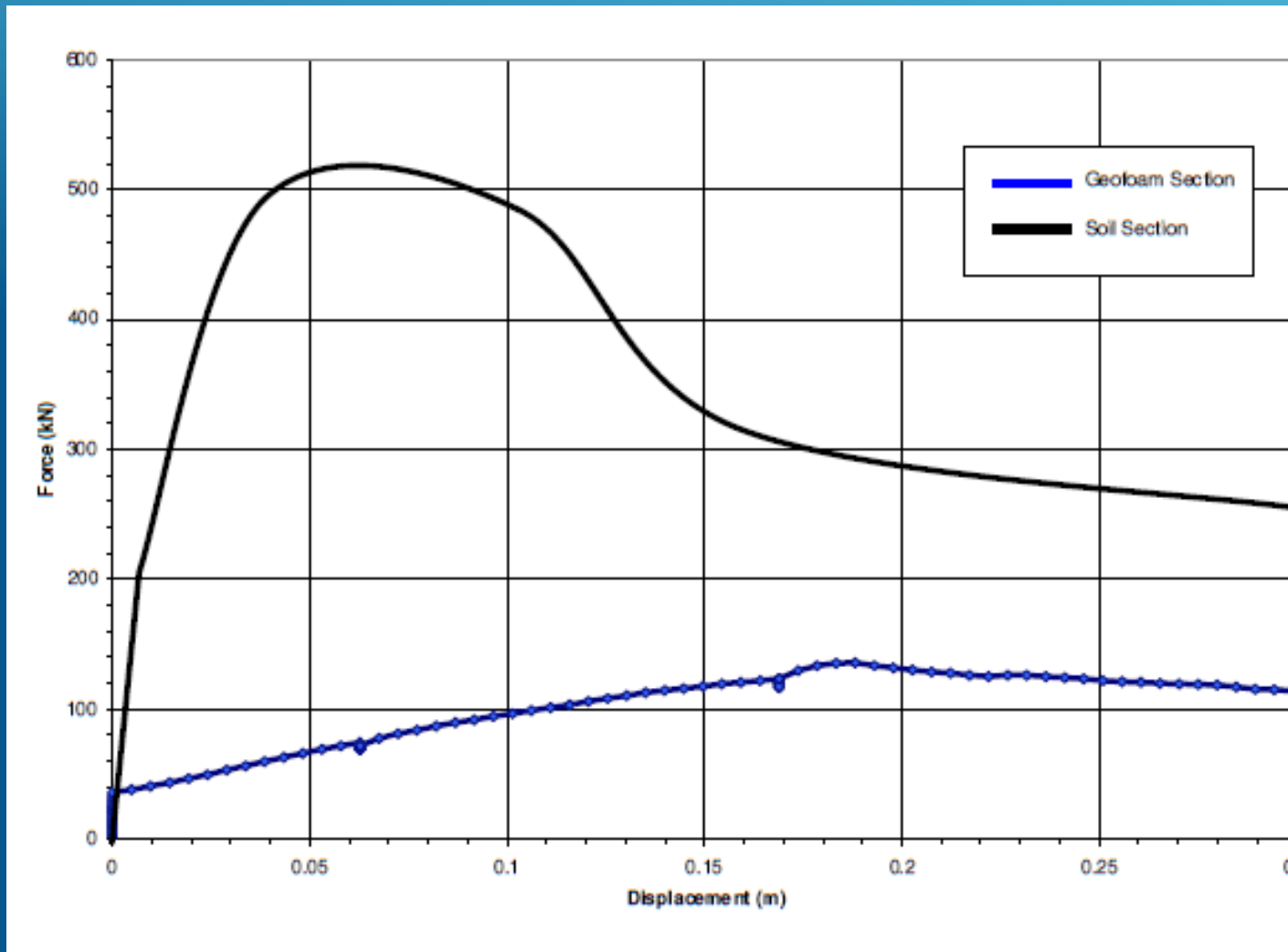


Lightweight-Cover System



Predicted Displacement Vectors During Failure

CULVERTS, PIPELINES AND BURIED STRUCTURES



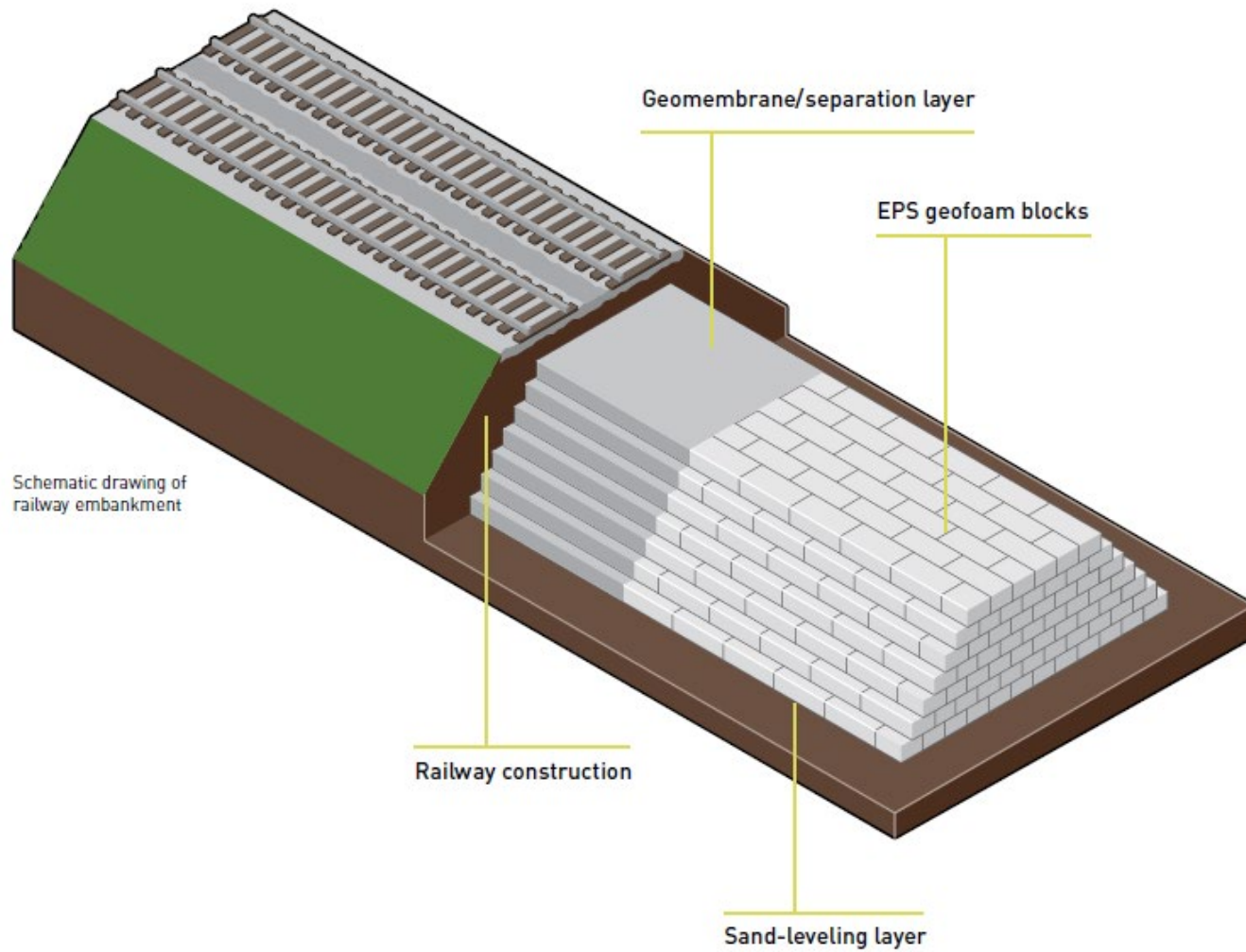
Force – Displacement Relation

CULVERTS, PIPELINES AND BURIED STRUCTURES

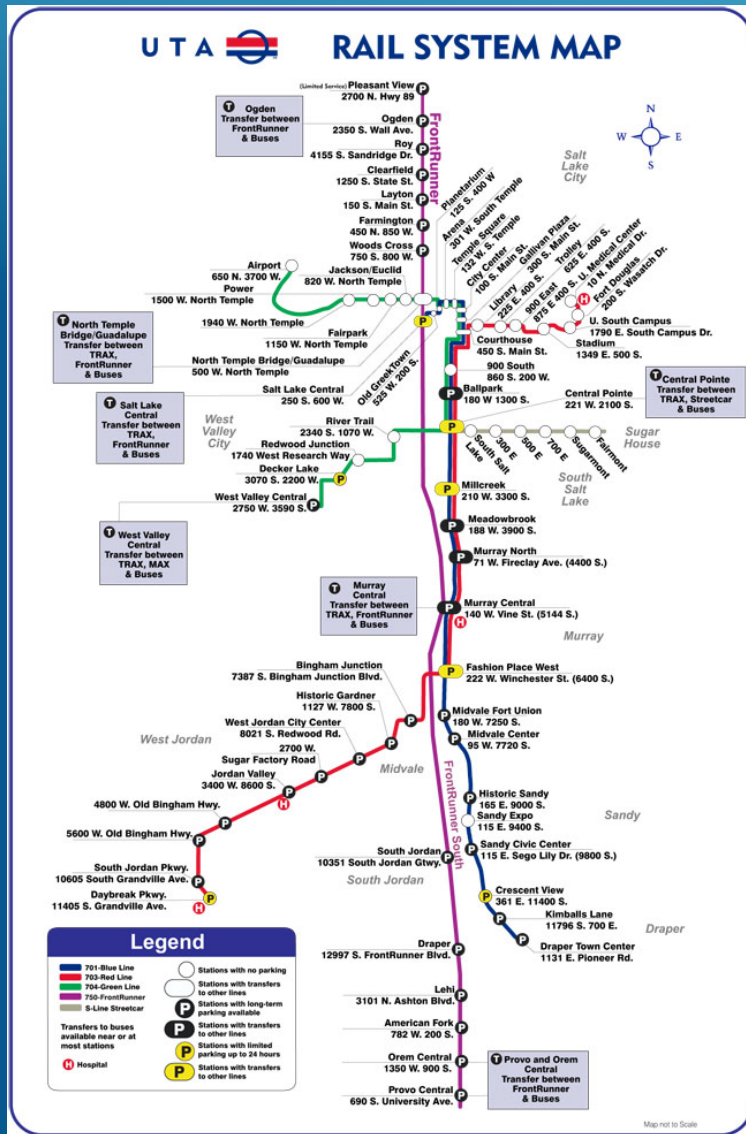


Questar Gas – Salt Lake City

RAIL EMBANKMENTS



UTAH TRANSIT AUTHORITY SYSTEM



Light rail system - TRAX



Commuter Rail system - Frontrunner

LIGHT RAIL EMBANKMENTS



UTA –Light Rail – Salt Lake City, Utah

LIGHT RAIL EMBANKMENTS



LIGHT RAIL EMBANKMENTS



UTA –Light Rail – Salt Lake City, Utah

COMMUTER RAIL EMBANKMENTS



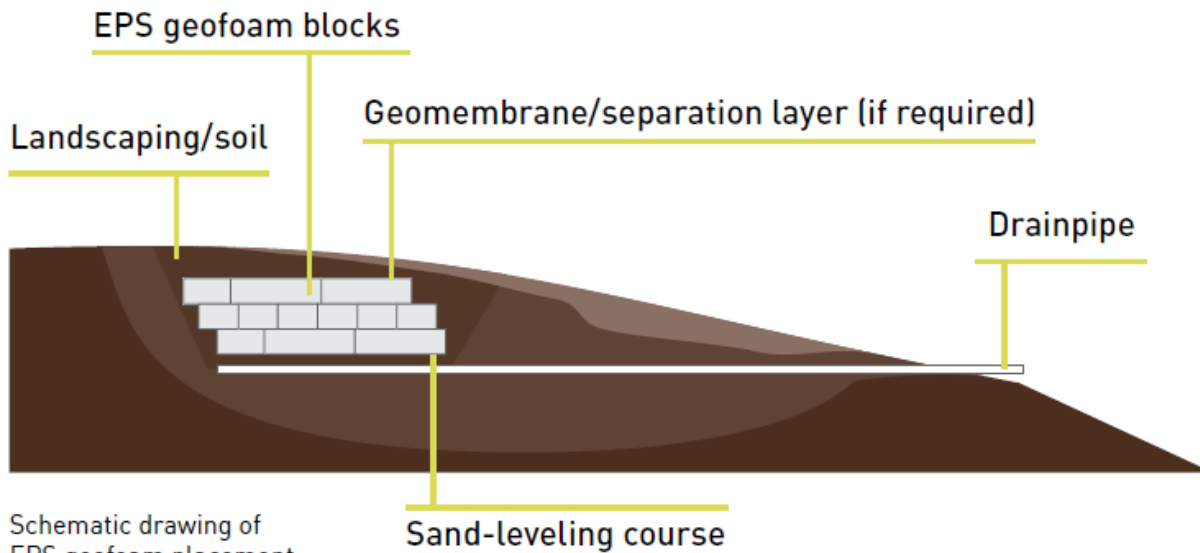
Front Runner – UTA – Corner Canyon – Draper Utah

Field Testing and Monitoring

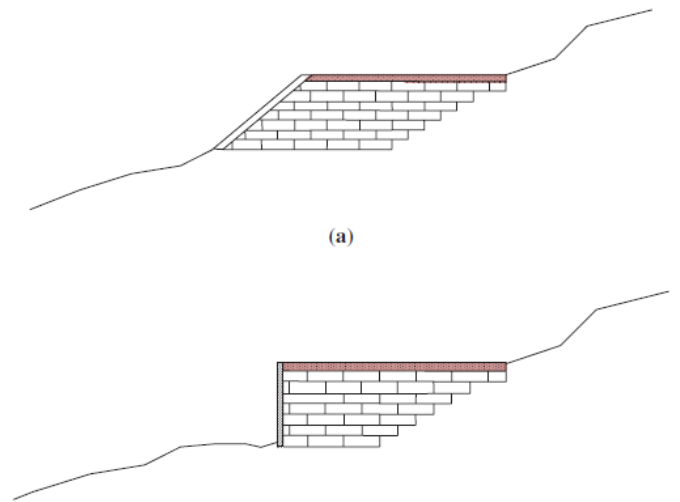
Deflection Monitoring for Rail Systems



SLOPE STABILIZATION



Schematic drawing of
EPS geofoam placement
in a slide area

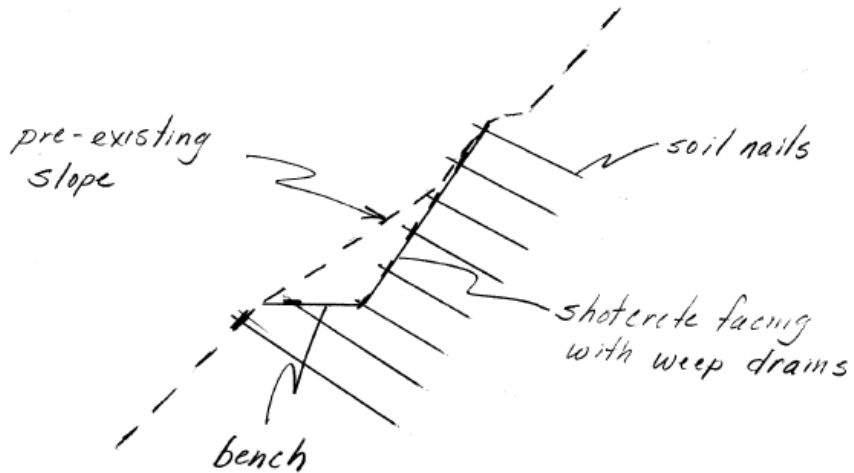


SLOPE REMEDIATION AND ROADWAY WIDENING – 2ND MESA ARIZONA



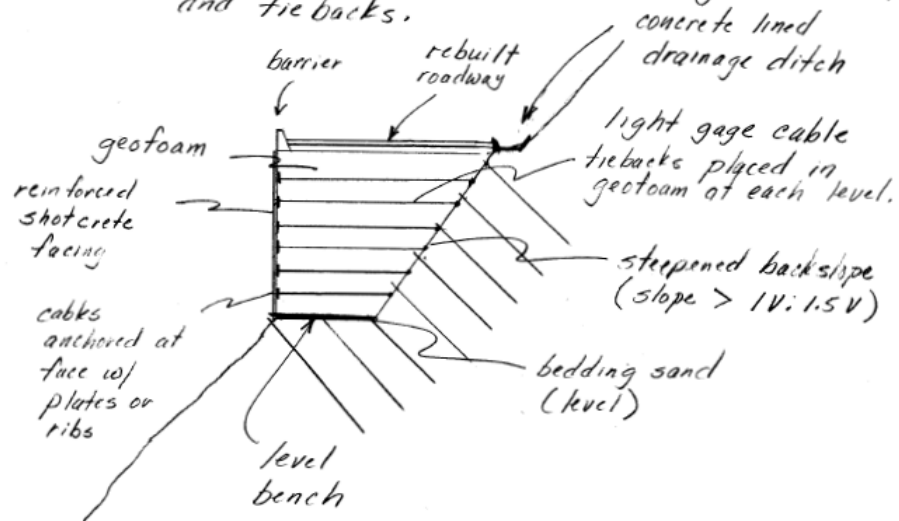
SOIL NAIL STABILIZATION OF SLOPE

Step 1 - Soil nailing and shotcreting of existing slope and create bench for geotextile placement.



PLACEMENT OF EPS

Step 2 - Rebuild slope and roadway with geofoam ^{2/4} and tiebacks.



CONSTRUCTION OF LOAD DISTRIBUTION SLAB



FINISHED ROADWAY



LANDSCAPING AND GREEN ROOFS

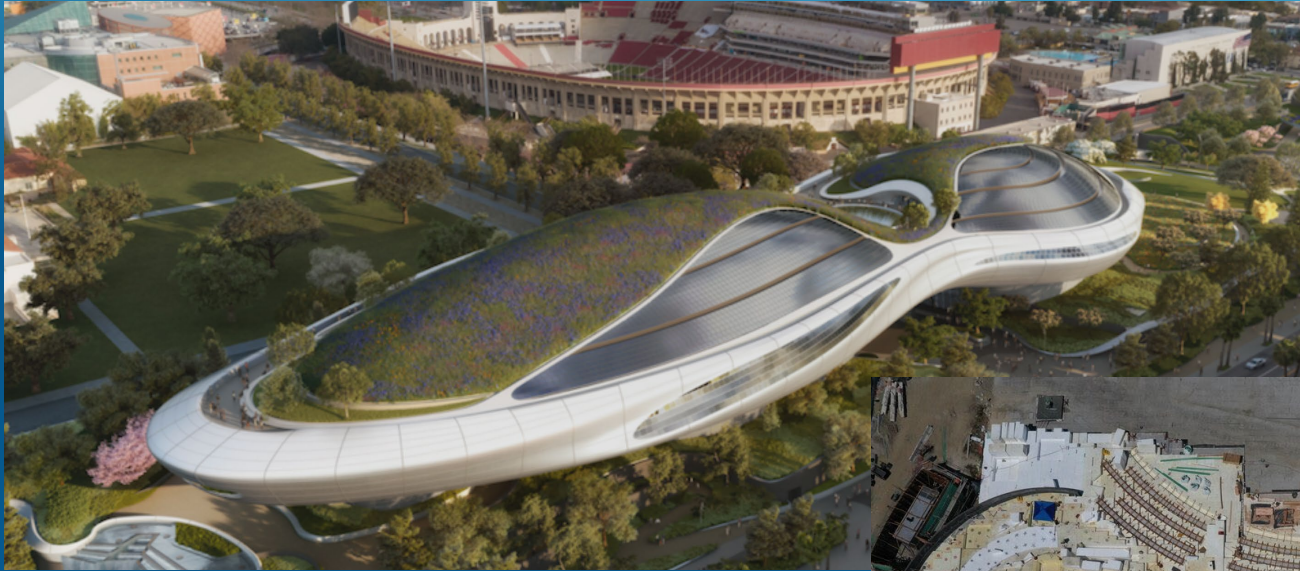


Disney Shanghai

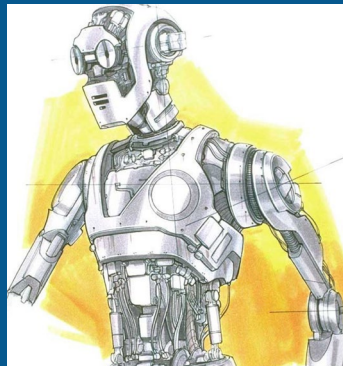


Example terraces
(Not from Disney
Project)

LANDSCAPING AND GREEN ROOFS



Conceptual View of
Lucas Museum, UCLA, California



Green Roof Example,
Not from Lucas Museum

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