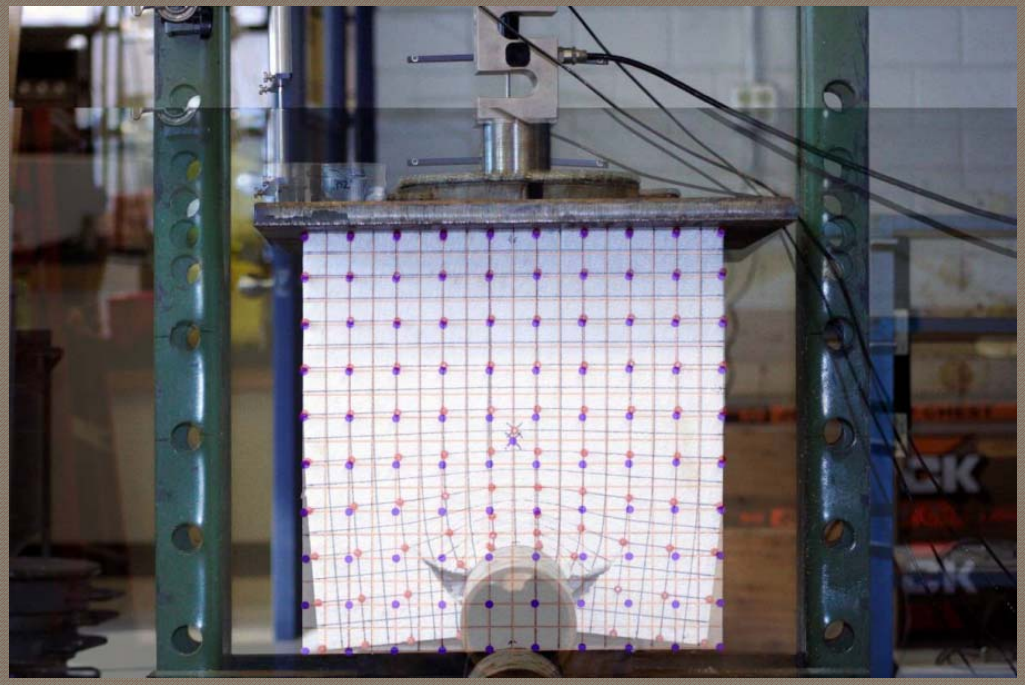
Protection of Pipelines from Permanent Ground Deformation Using EPS Geofoam

BASIN AND RANGE PROVINCE SEISMIC HAZARDS SUMMIT III



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Topics

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- Seismic Hazards
- Pipeline Protection Strategies
- Development of EPS Light-weight Cover
- Test Results
- Field Application

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Beginnings of Geofoam in Civil Engineering Applications

Flom Bridge – 1972 - Norway

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Geofoam Properties

ASTM D6817 Physical Property Requirements of EPS Geofoam

Type	EPS12	EPS15	EPS19	EPS22	EPS29	EPS39	EPS46
Density, min., kg/m^3(lb/ft^3)	11.2 (0.70)	14.4 (0.90)	18.4 (1.15)	21.6 (1.35)	28.8 (1.80)	38.4 (2.40)	45.7 (2.85)
Compressive Resistance, min., kPa (psi) at 1 %	15 (2.2)	25 (3.6)	40 (5.8)	50 (7.3)	75 (10.9)	103 (15.0)	128 (18.6)
Compressive Resistance, min., kPa (psi) at 5 %	35 (5.1)	55 (8.0)	90 (13.1)	115 (16.7)	170 (24.7)	241 (35.0)	300 (43.5)
Compressive Resistance, min., kPa (psi) at 10 %[A]	40 (5.8)	70 (10.2)	110 (16.0)	135 (19.6)	200 (29.0)	276 (40.0)	345 (50.0)
Flexural Strength, min., kPa (psi)	69 (10.0)	172 (25.0)	207 (30.0)	240 (35.0)	345 (50.0)	414 (60.0)	517 (75.0)
Oxygen index, min., volume %	24.0	24.0	24.0	24.0	24.0	24.0	24.0

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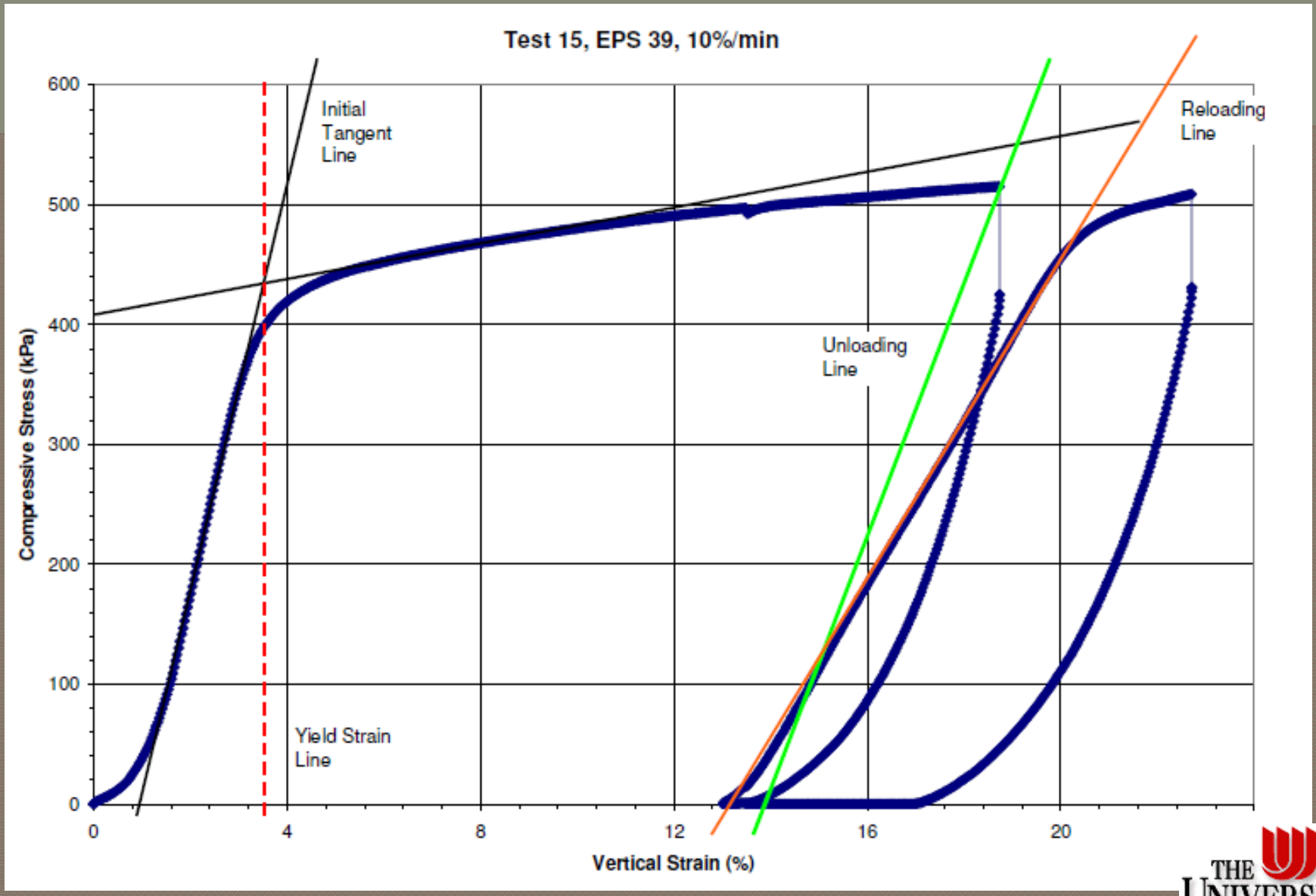
Geofoam Properties Under Monotonic Loading



Lingwall and Bartlett (2010)

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Block Compression Tests

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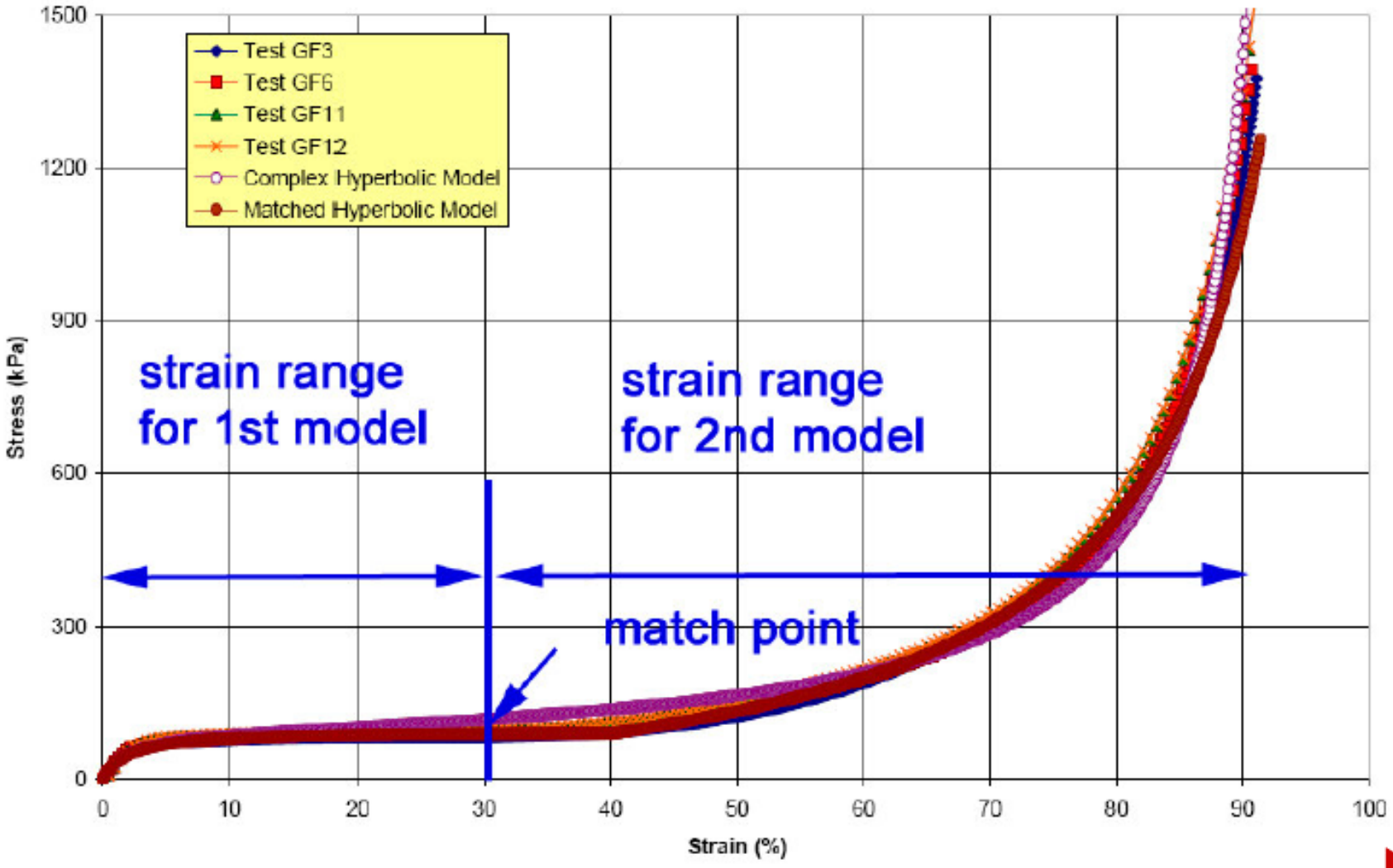
Geofoam Large Strain Behavior



Typical Stress – Strain Curve for EPS (Lingwall and Bartlett, 2010)

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Geofoam Advantages

- Light weight material
  - Reduces static and seismic loads to walls, buried structures
  - Improves slope stability (static & dynamic)
  - Reduces consolidation settlement on soft ground
- Controlled Compression (Compression Inclusion)
  - Can undergo elastic and plastic deformation but maintains general shape
  - Reduces loads to buried structures by compression and mobilization of soil's shear strength in the surrounding area

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Sources of Permanent Ground Deformation

- Tectonic Faulting
- Subsidence and Settlement
- Landsliding and Other Types of Mass Movement
- Liquefaction and Lateral Spread

Light-weight cover system can offer a potential solution to many of these types of ground displacement, but more development is need.

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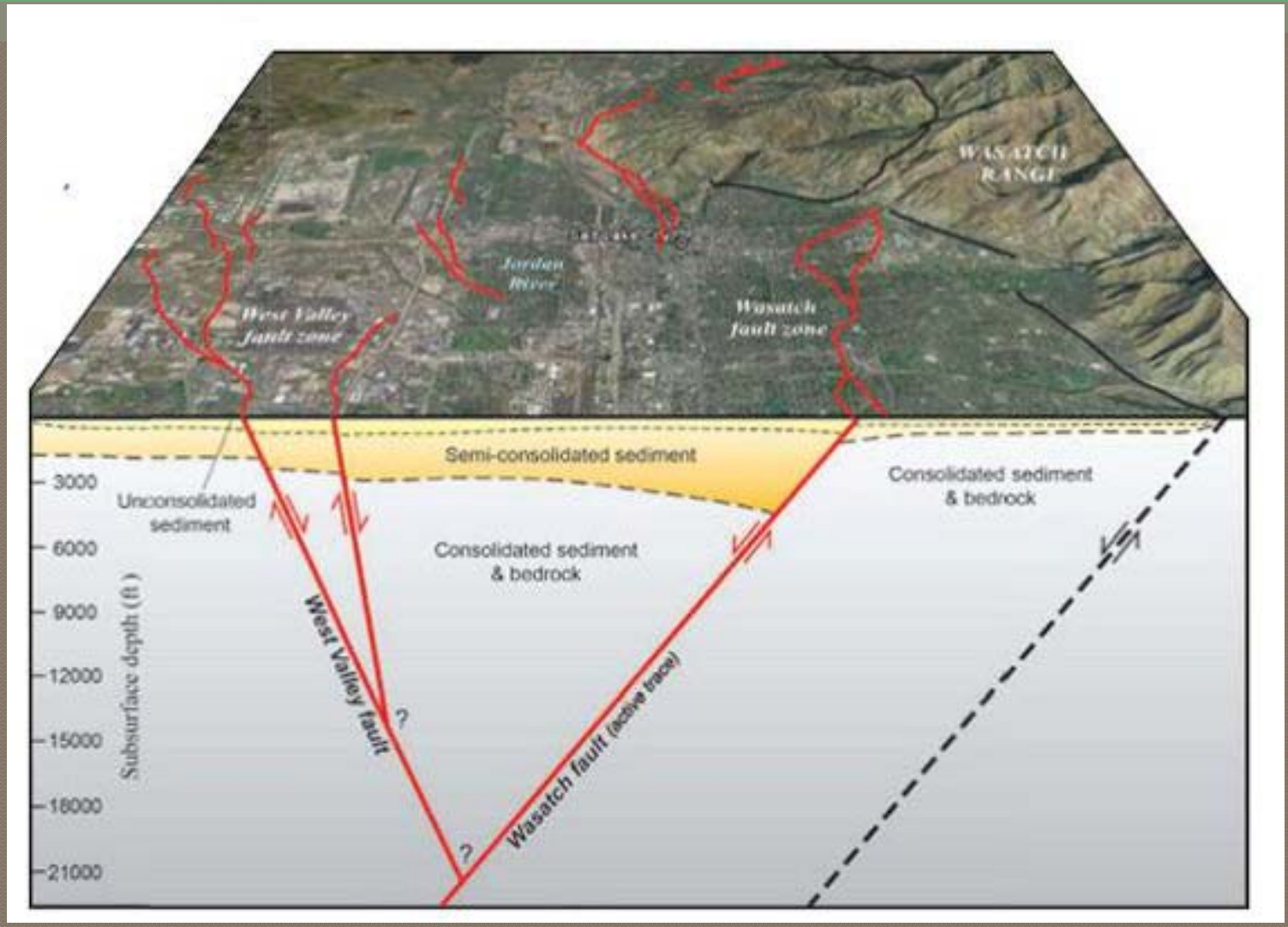
Wasatch Fault – Salt Lake City Segment



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Wasatch Fault at Little Cottonwood Canyon

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Fault-Induced Pipeline Rupture

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Pipeline Protection Strategies

- Mechanical Devices
  - Expensive
  - Cannot easily remediate existing problem
  - Proprietary
  - Tend to induce extra axial forces on pipeline

http://www.wateronline.com/product.mvc

Pipelines (Protection for Strike Slip Faults)

Alaskan Pipeline – Strike Slip Fault

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Pipelines (Protection for Normal and Reverse Faults)

Shallow Burial – Normal Faulting

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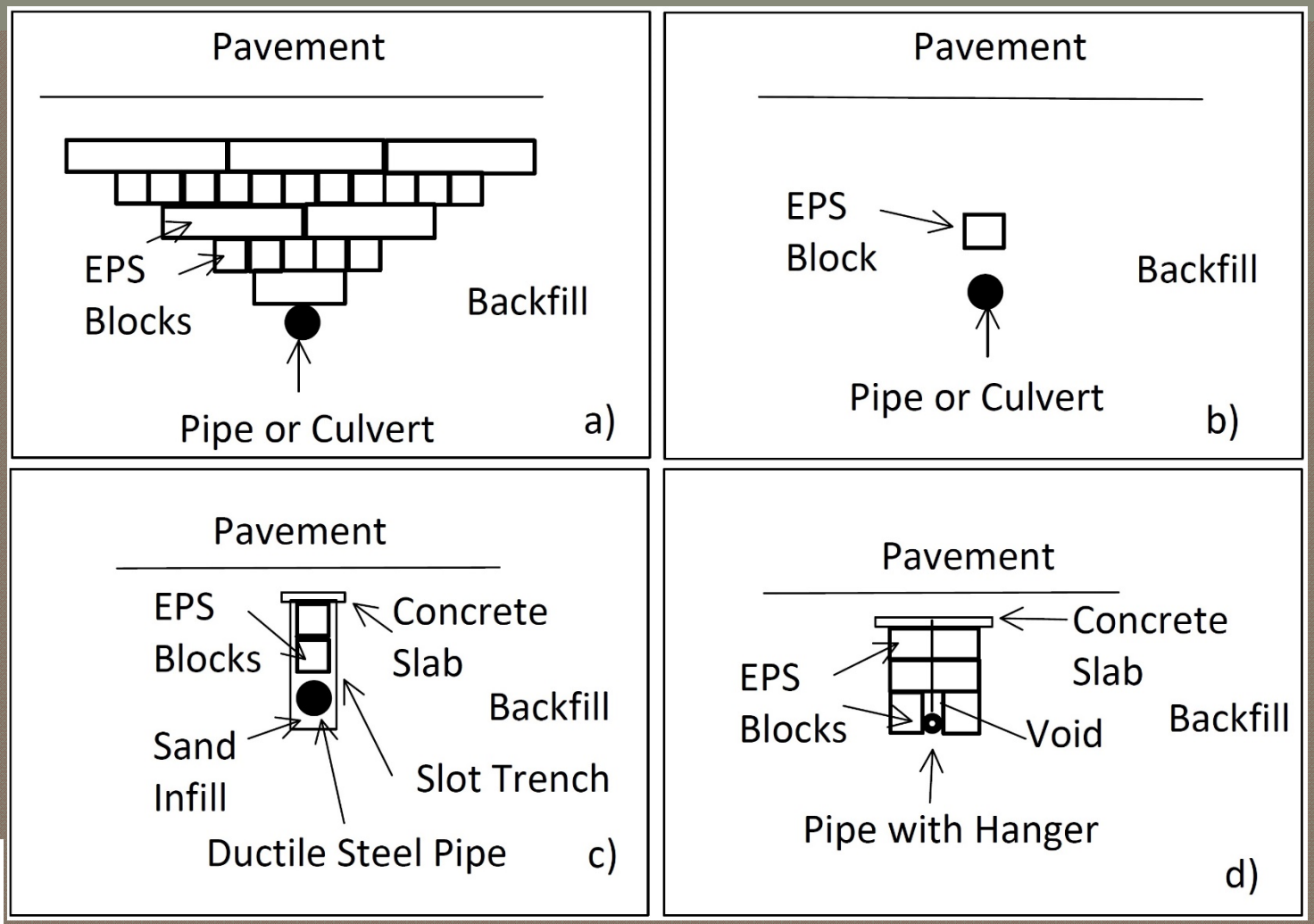
Common EPS Protection Strategies



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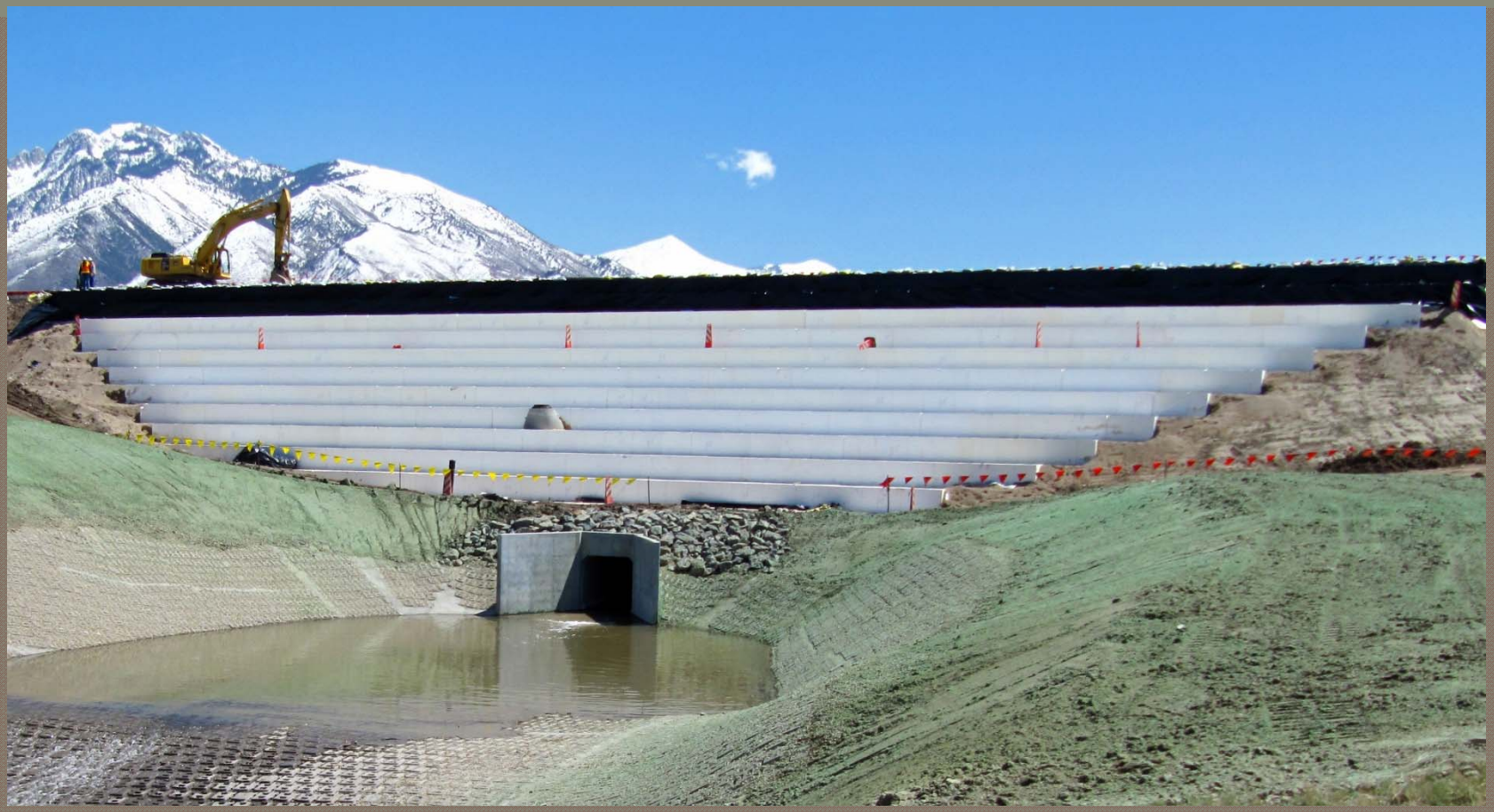
Light-weight Cover



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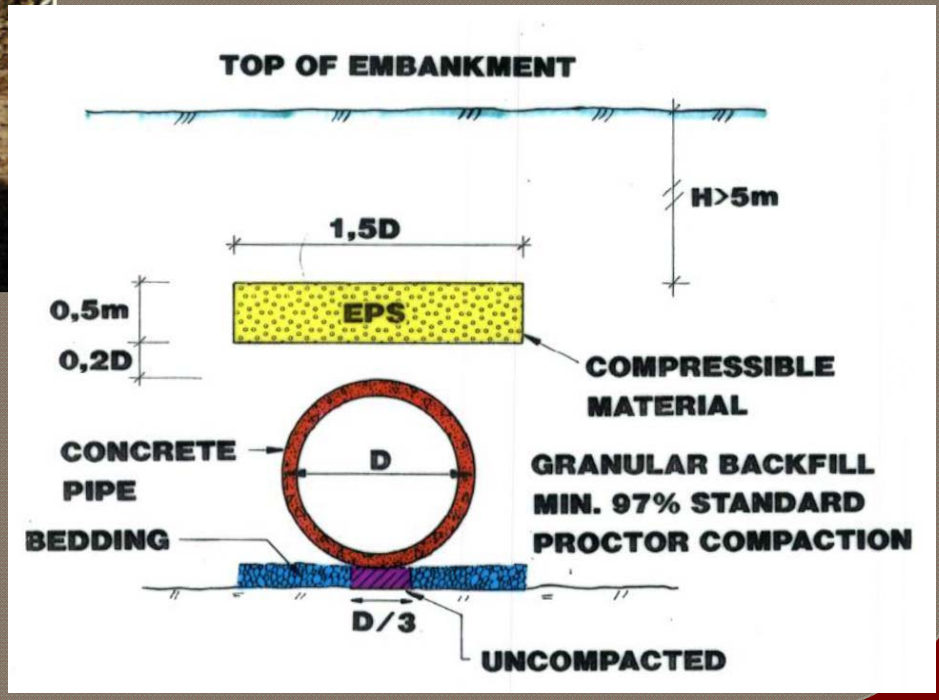
UTA Front Runner System, Corner Canyon, Draper, Utah (photo courtesy of ACH Foam)

Compressible Inclusion – Imperfect Trench Method

Eidanger, Norway 1988 (photo courtsey of Norwegian Public Roads Administation).



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Slot Trench Cover System

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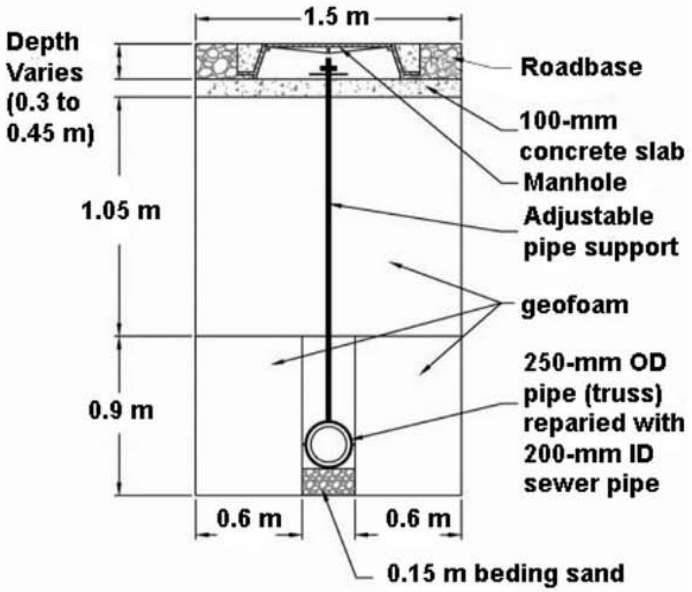
Salt Lake City, Utah

Post and Beam Cover System



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Brian Head Ski Resort, Cedar City, Utah

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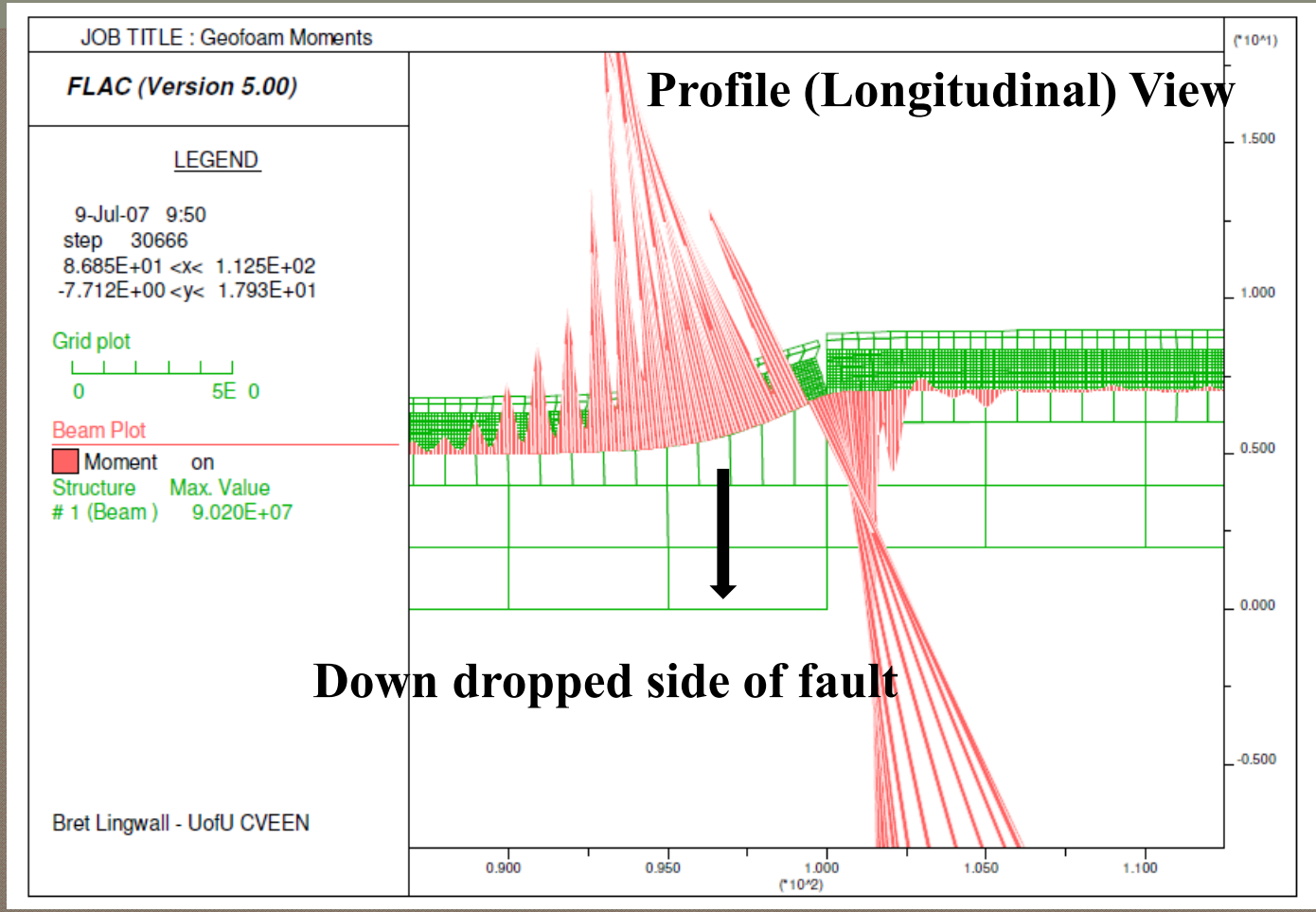
Pipelines (Light-weight Cover Over Normal Faults)



Bending Moments in Pipe from 2 m offset

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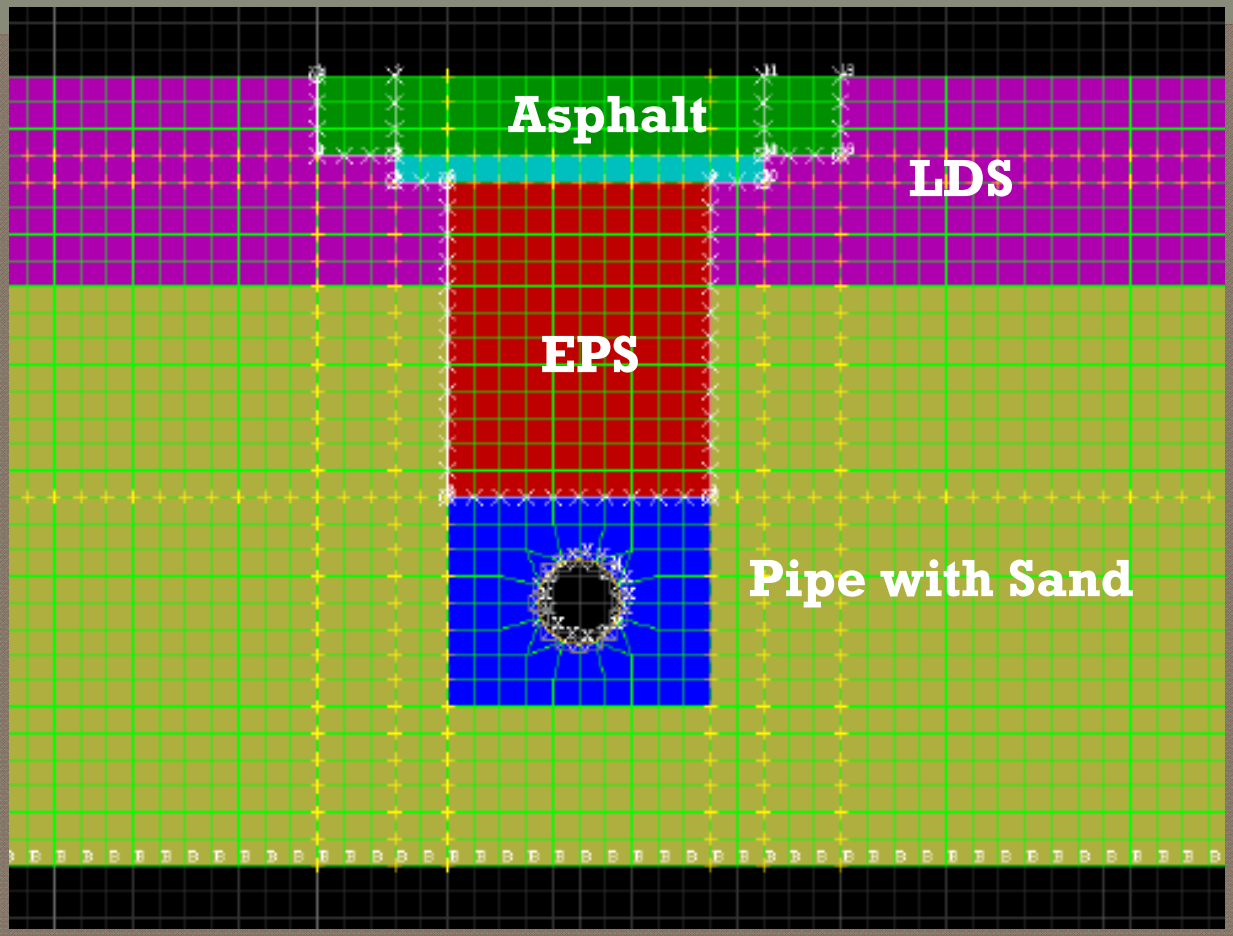
Pipelines (Light-weight Cover Over Normal Faults)



Lightweight-Cover System
(X-sectional View)

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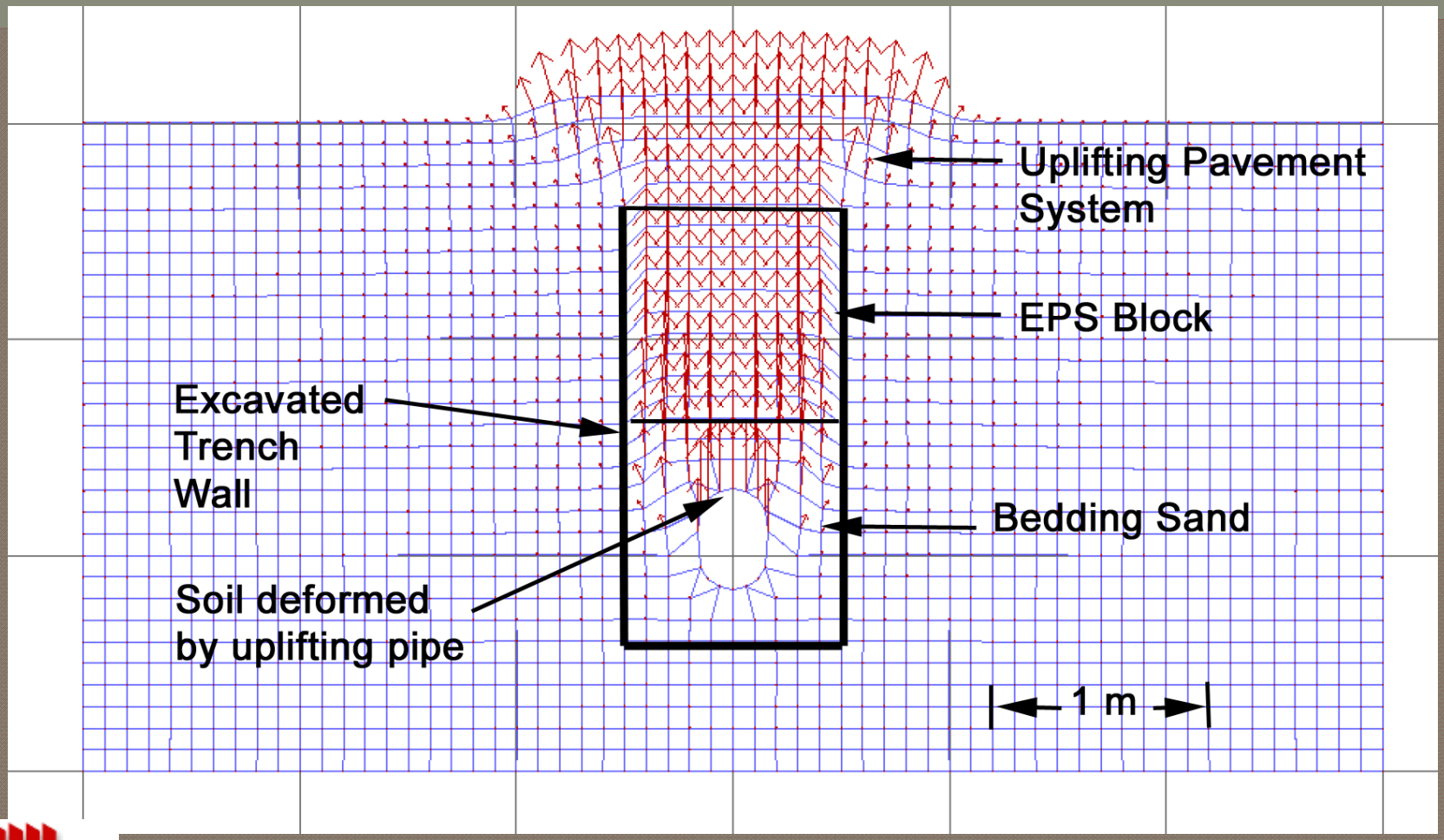
Pipelines (Light-weight Cover Over Normal Faults)



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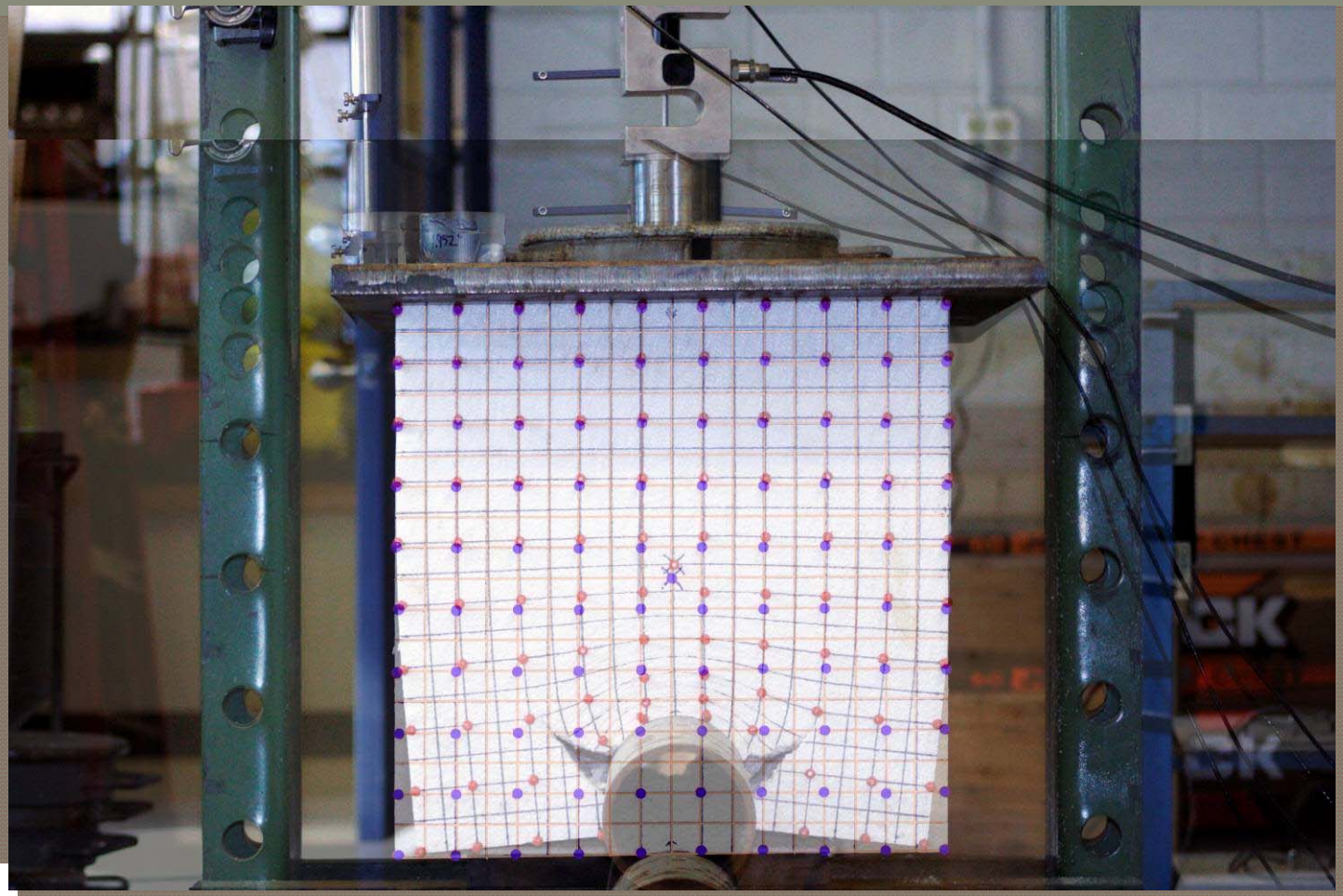
Displacement Vectors During Failure

Geofoam Pipe Interaction



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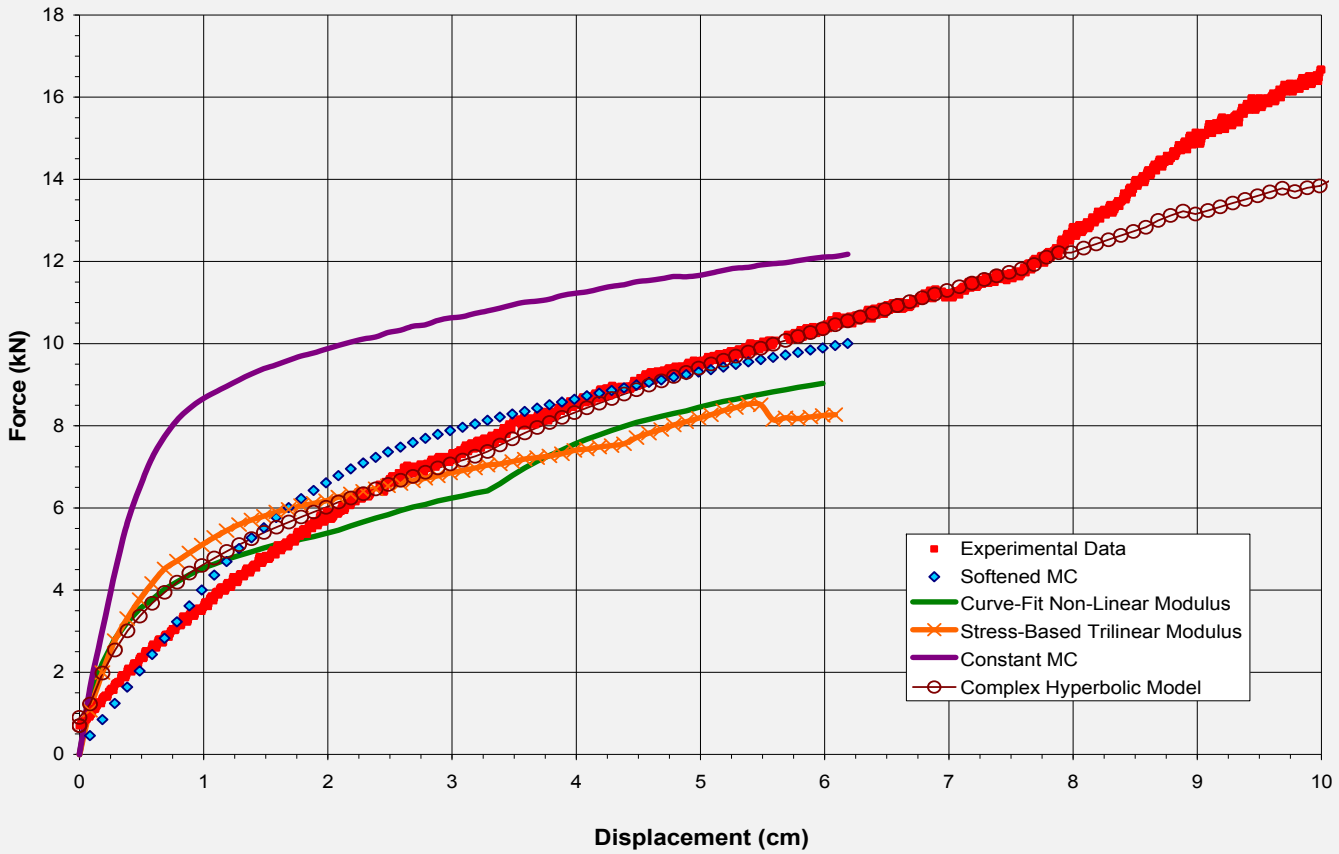
Geofoam Pipe Interaction Modeling



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Construction of Uplift Tests

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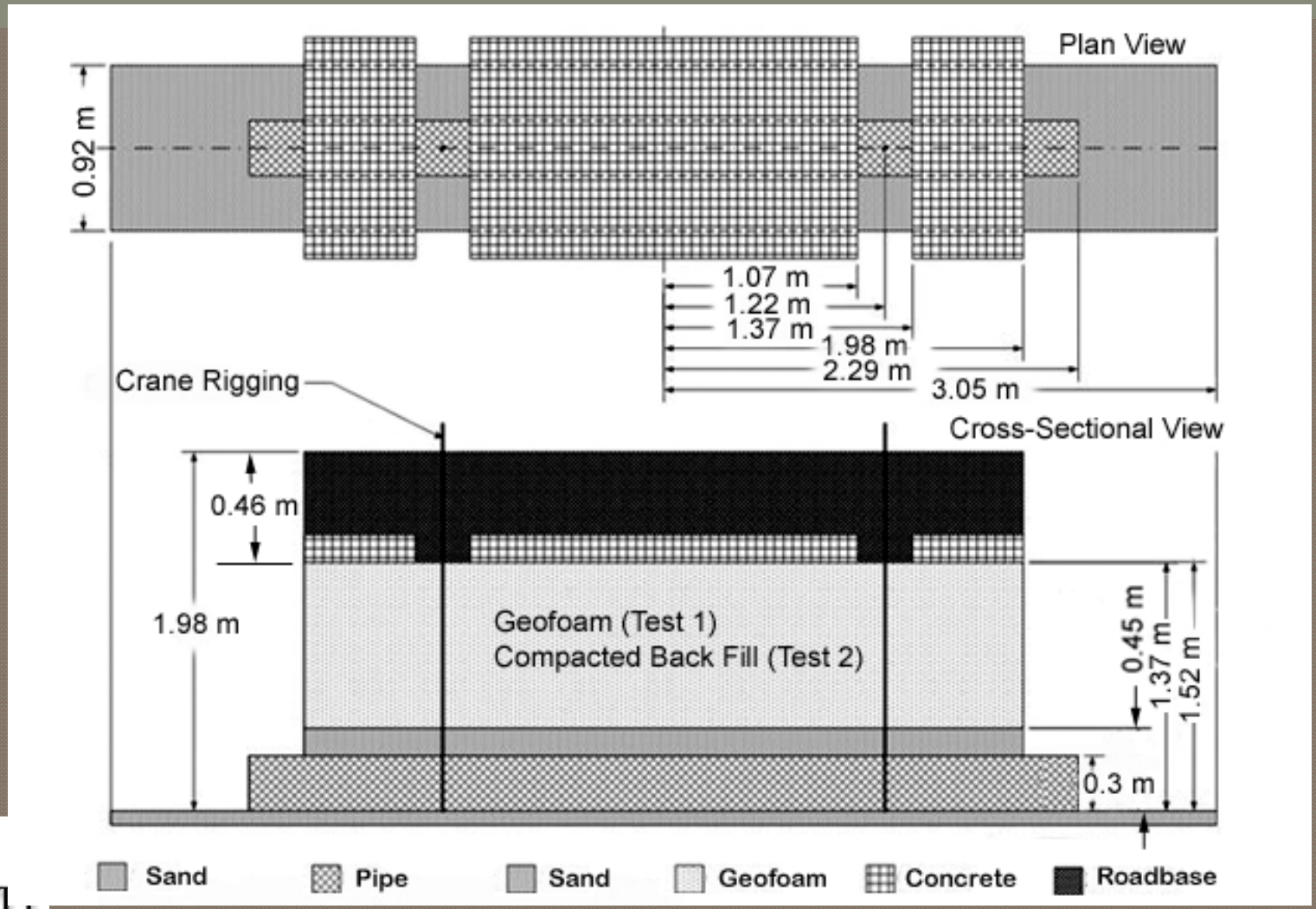
Lift-up Test Layout



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Vertical Uplift Tests

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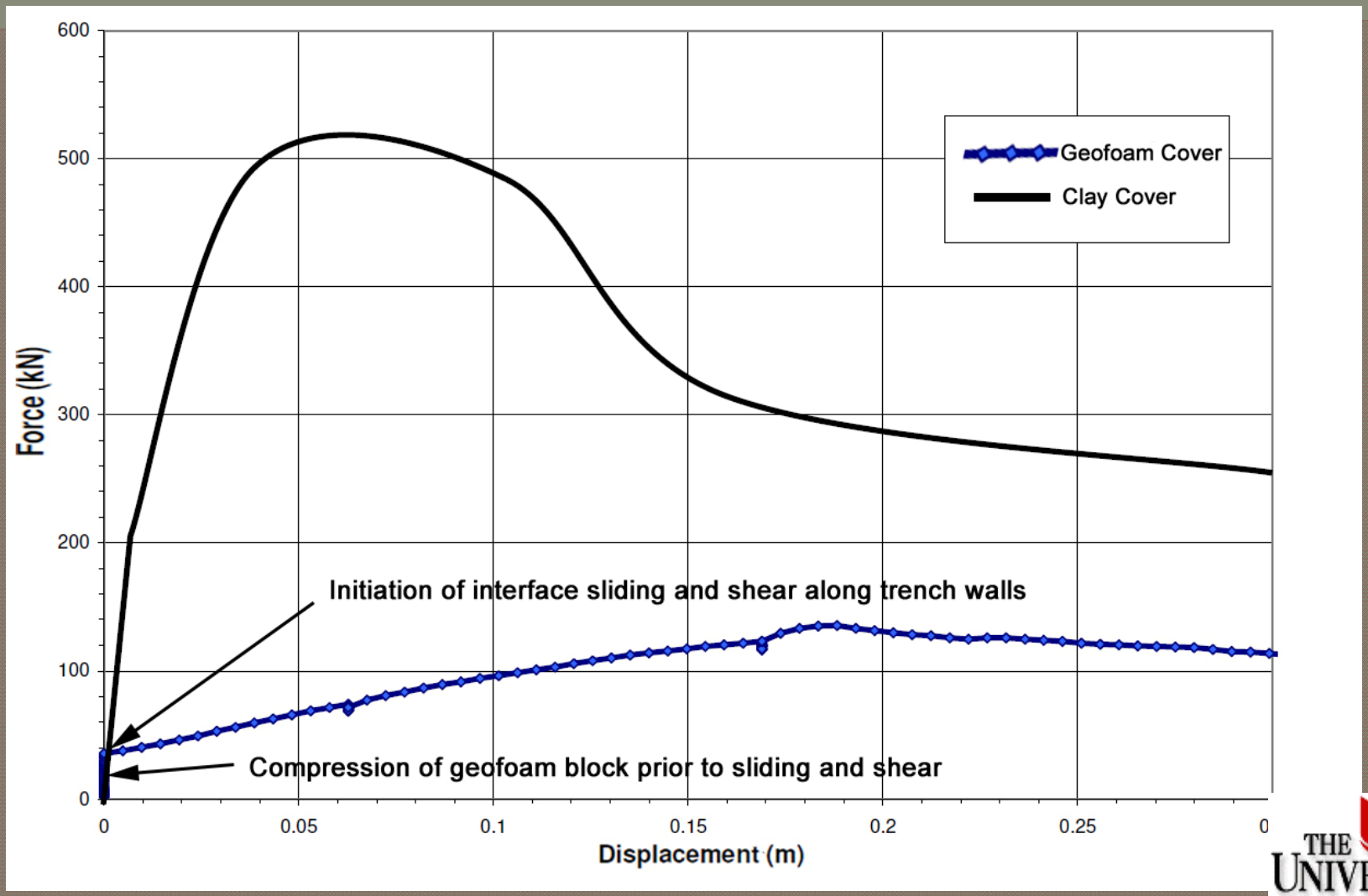
Force-Displacement Curves from Uplift Tests



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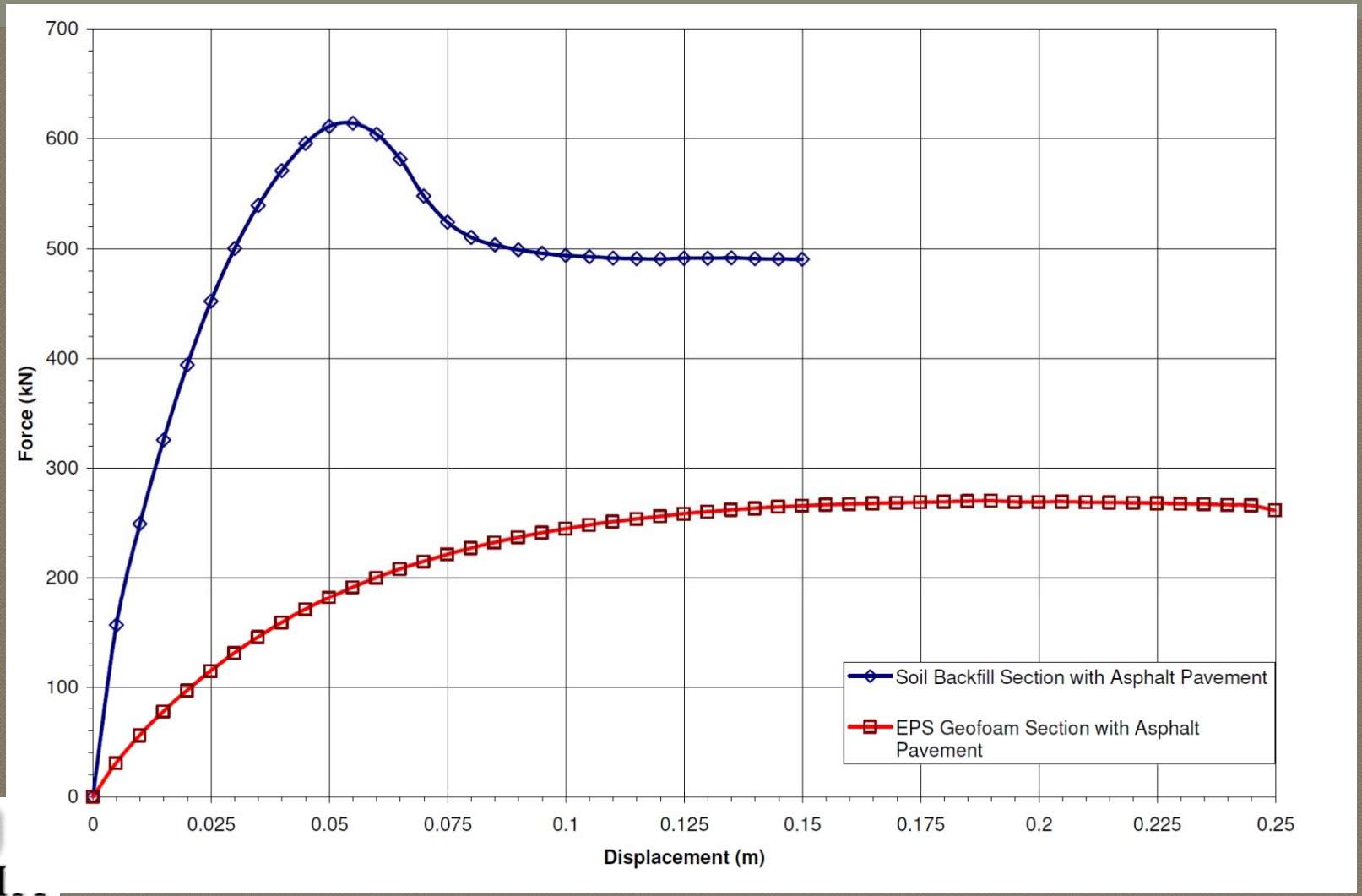
Results of Numerical Modeling of Cover with Asphalt



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500 South Fault Crossing – Salt Lake City, Utah

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Conclusions

- Light weight EPS cover systems can be effective in preventing rupture of high strength steel-pipelines undergoing vertical offset from permanent ground displacement.
- The EPS light-weight cover strategy presumes that surface damage caused by uplift of the cover is acceptable.
- Light weight cover systems can also be used to accommodate horizontal movement.

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For More Information

http://www.civil.utah.edu/~bartlett/Geofoam/