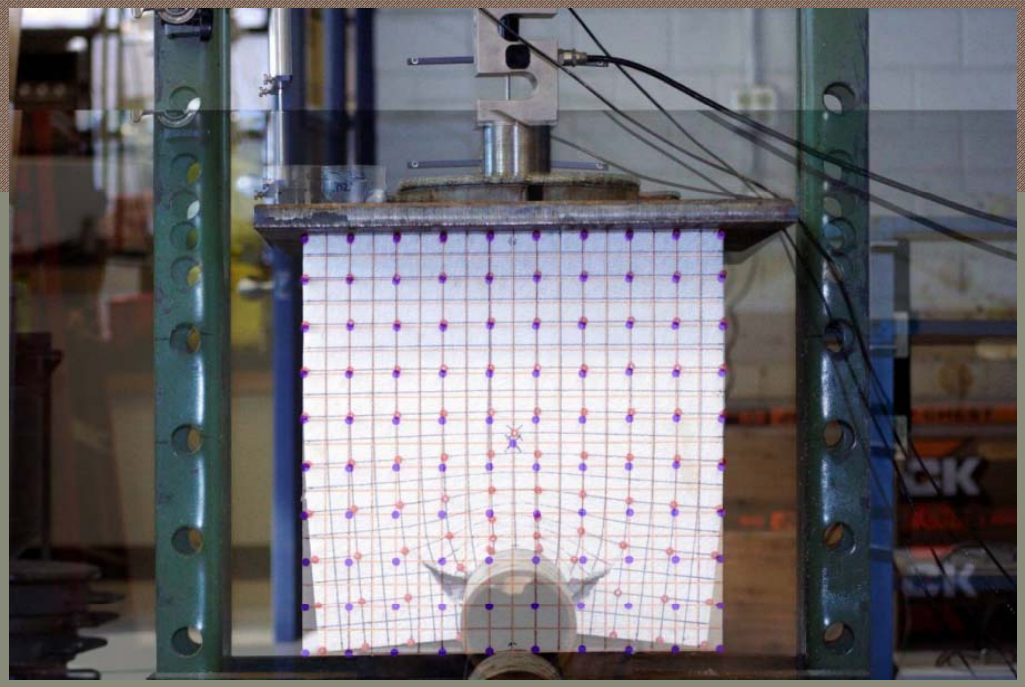
Protection of Lifelines and Buried Structures Using EPS Geofoam
GeoShanghai 2014



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Topics

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

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Beginnings of Geofoam

Flom Bridge – 1972 - Norway

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Common Civil Engineering Applications

Light-weight embankment

Slope stabilization

Light-weight backfill

Green Roofs and Landscaping

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 load to buried structures by compression

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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/m³(lb/ft³)	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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General Applications of EPS Geofoam

2.1	Road construction over poor soils
2.2	Road widening
2.3	Bridge abutment
2.4	Bridge underfill
2.5	Culverts, pipelines & buried structures
2.6	Compensating foundation
2.7	Rail embankment
2.8	Landscaping & vegetative green roofs
2.9	Retaining and buried wall backfill
2.10	Slope stabilization
2.11	Stadium & theater seating
2.12	Levees
2.13	Airport runway/taxiway
2.14	Foundations for lightweight structures

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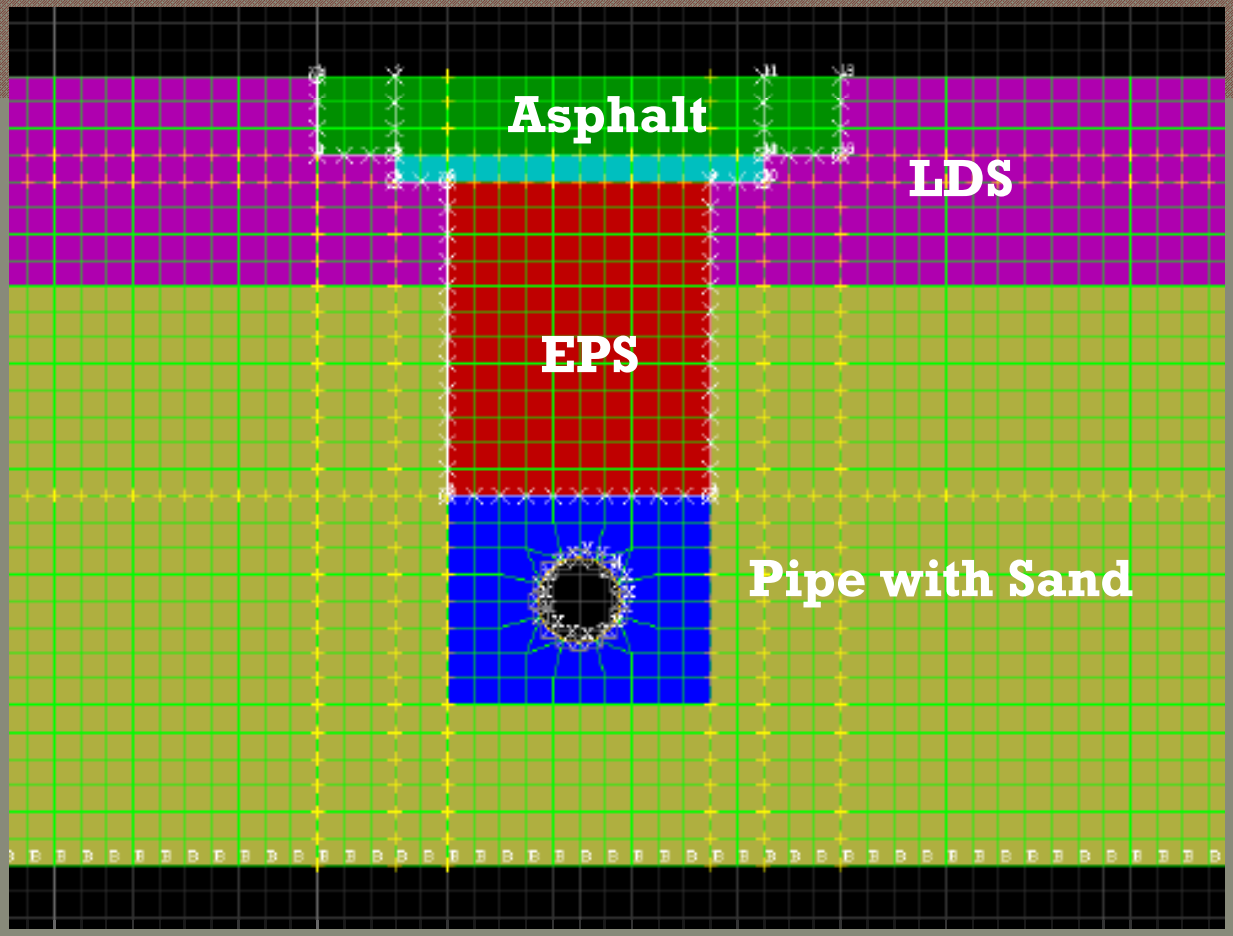
Pipelines (Light-weight Cover Over Normal Faults)



Lightweight-Cover System
(X-sectional View)

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Geofoam Monotonic and Cyclic Testing

GeoComp™ Cyclic Triaxial Device

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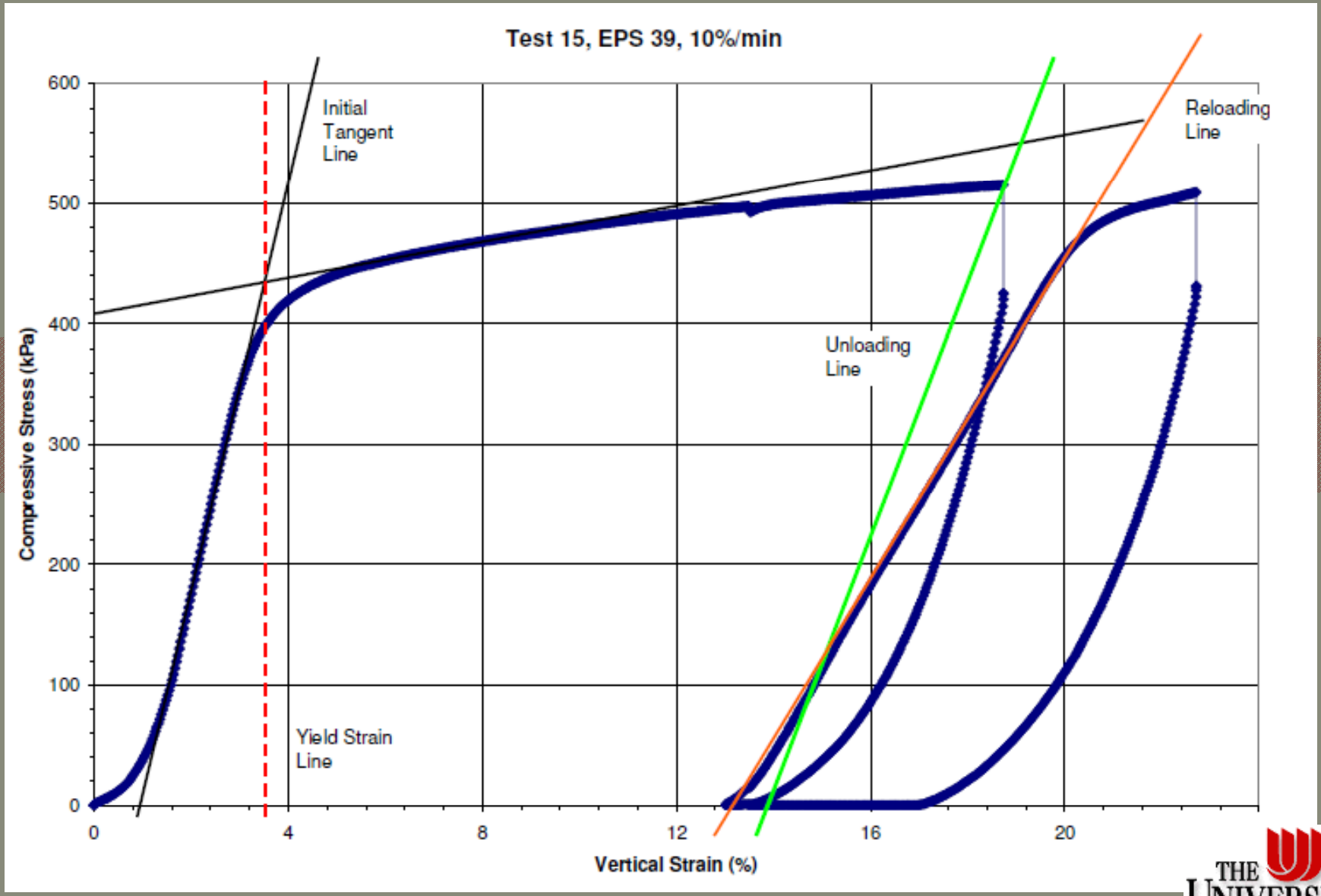
Geofoam Properties Under Monotonic Loading



Lingwall and Bartlett (2010)

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Full-Scale Compression Test

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Block Compression Tests

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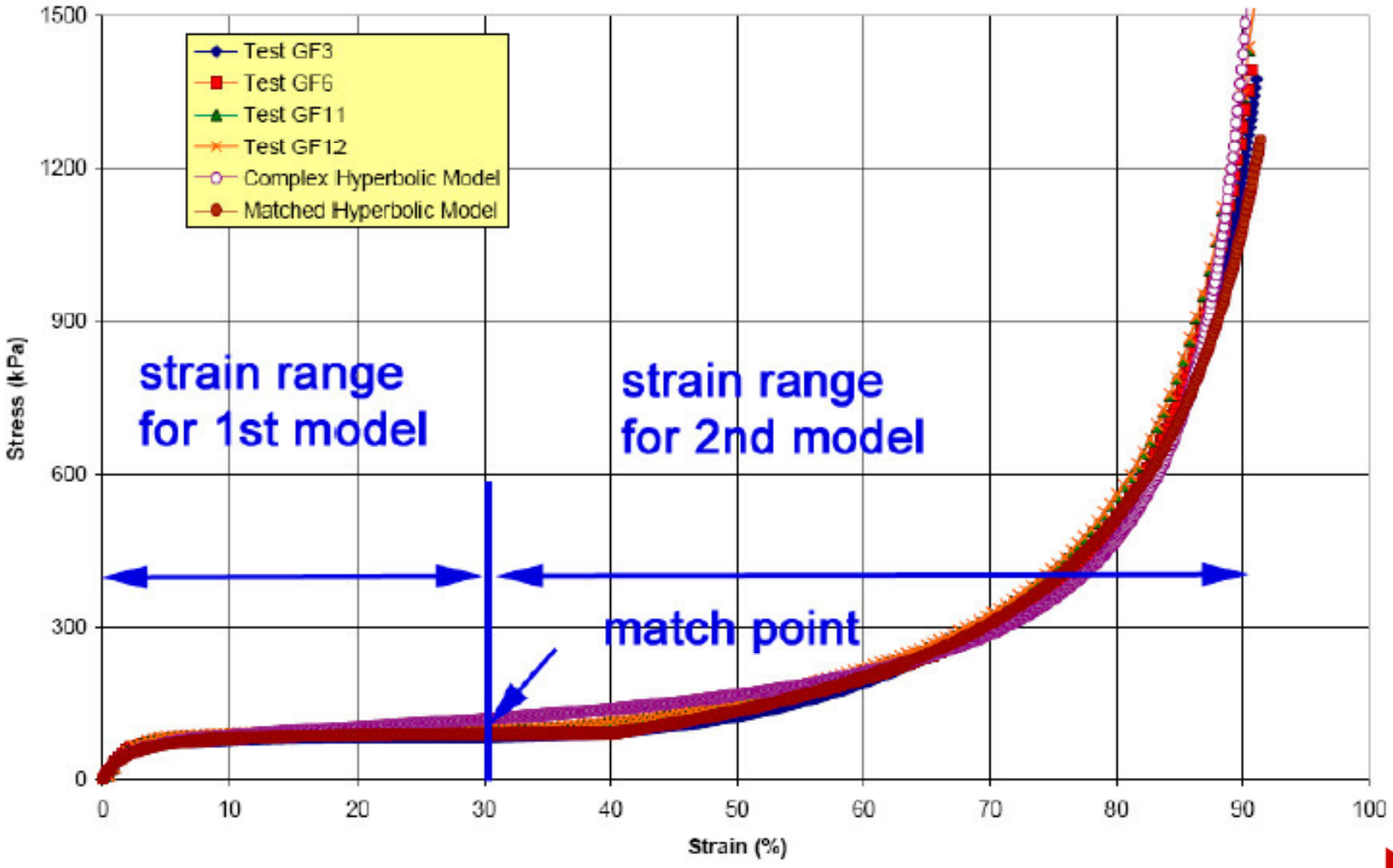
Geofoam Large Strain Behavior



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

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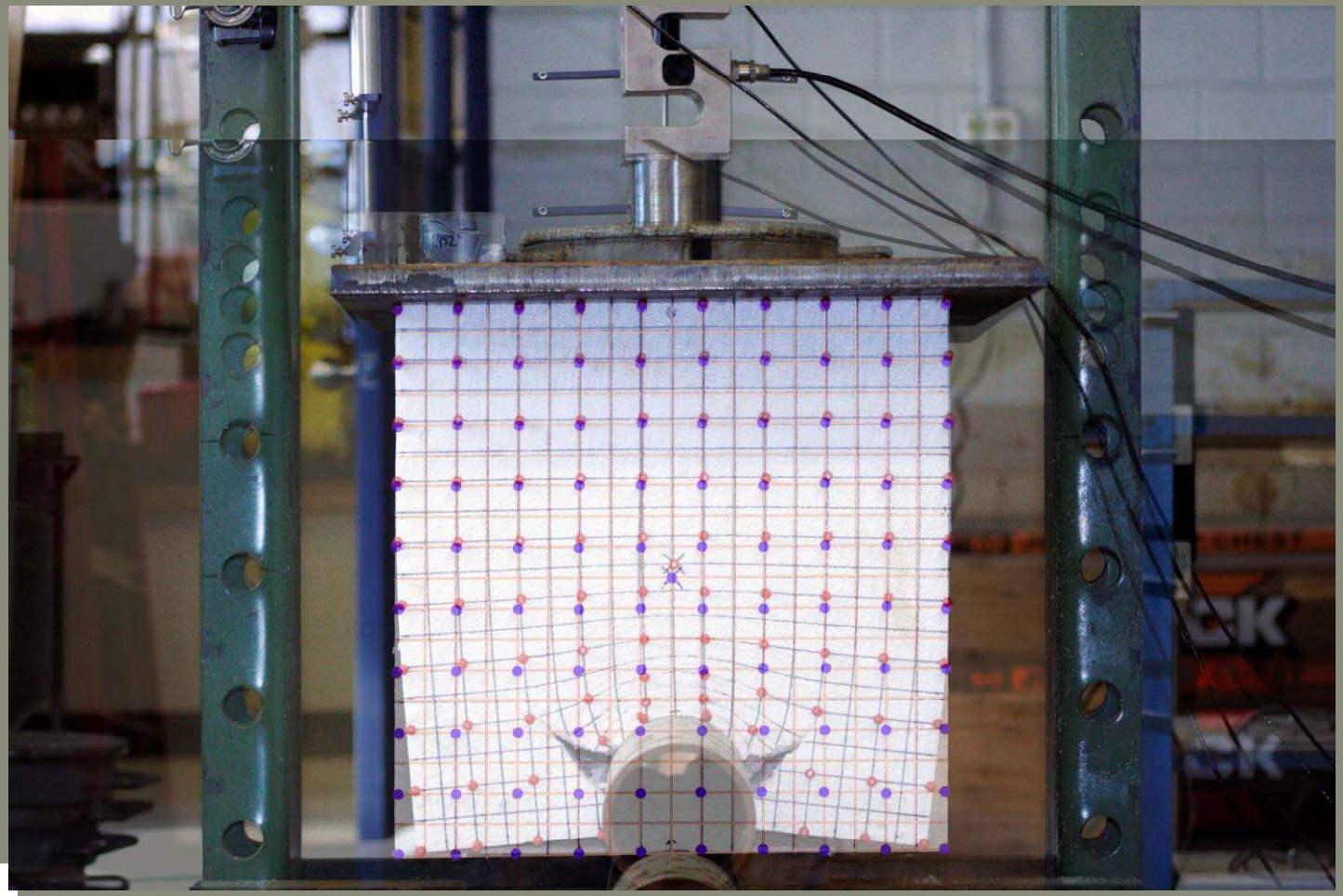
Geofoam Pipe Interaction



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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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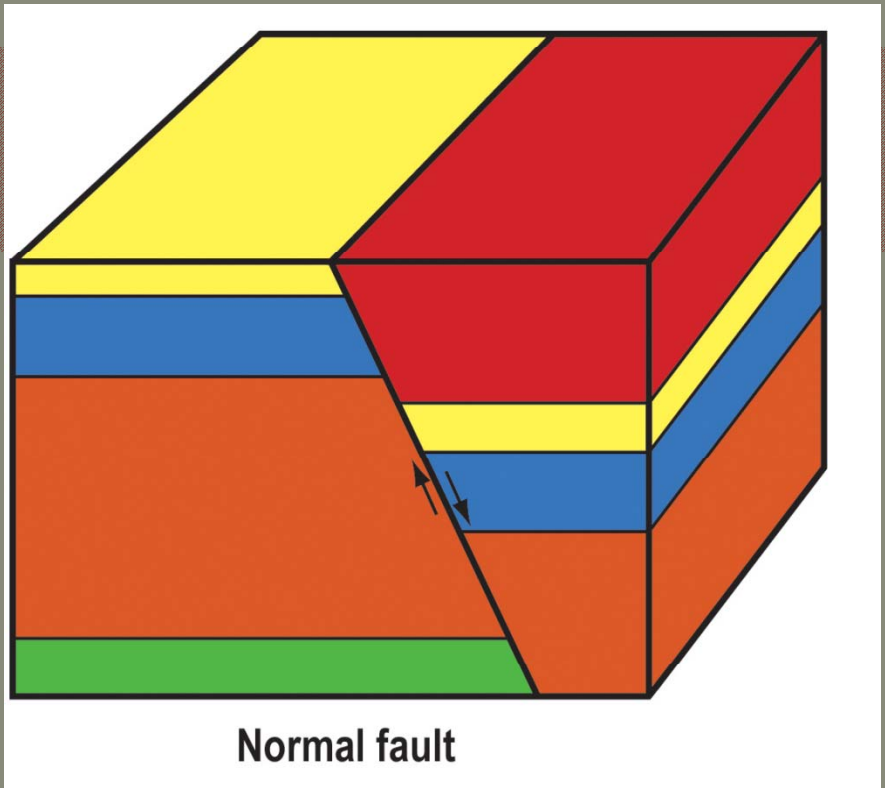
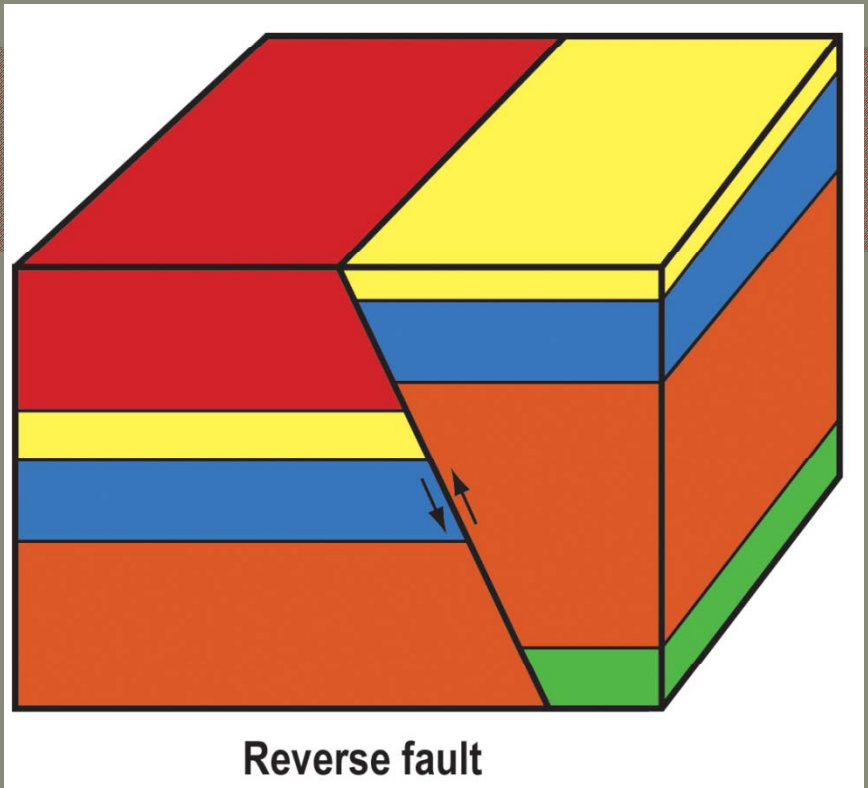
Faults with Vertical Movement (Dip-Slip Faults)



Normal fault



Reverse fault

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Salt Lake City, Index Map

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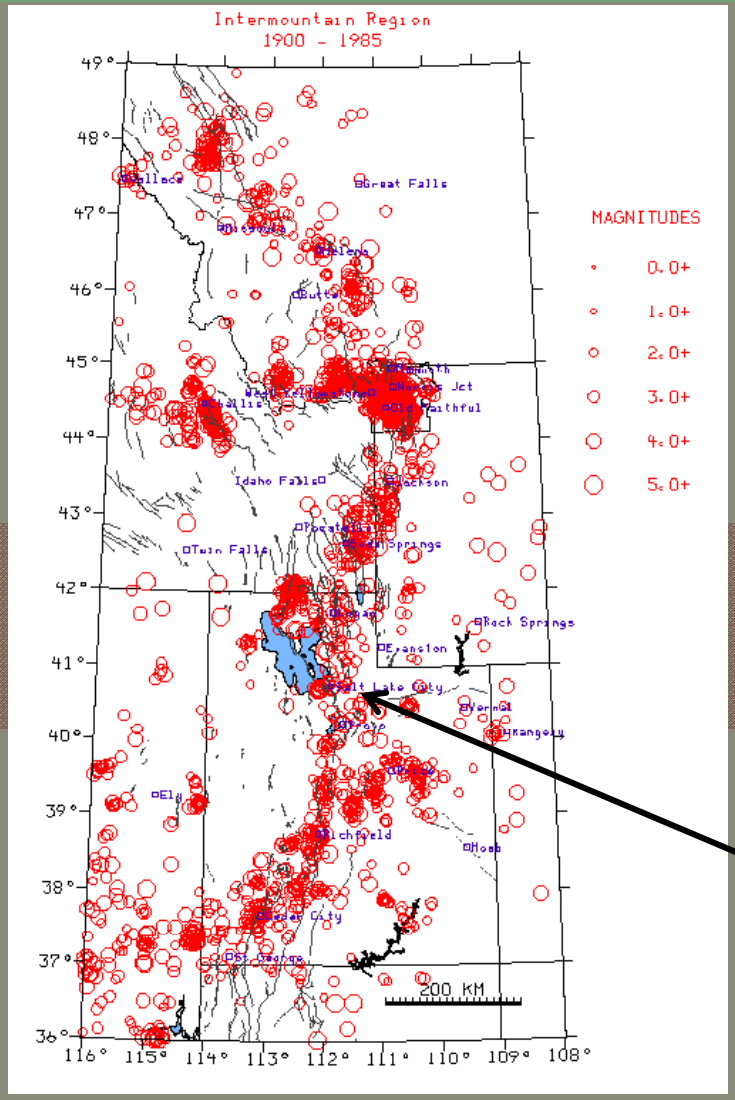
Seismicity of Intermountain Seismic Belt



Salt Lake City

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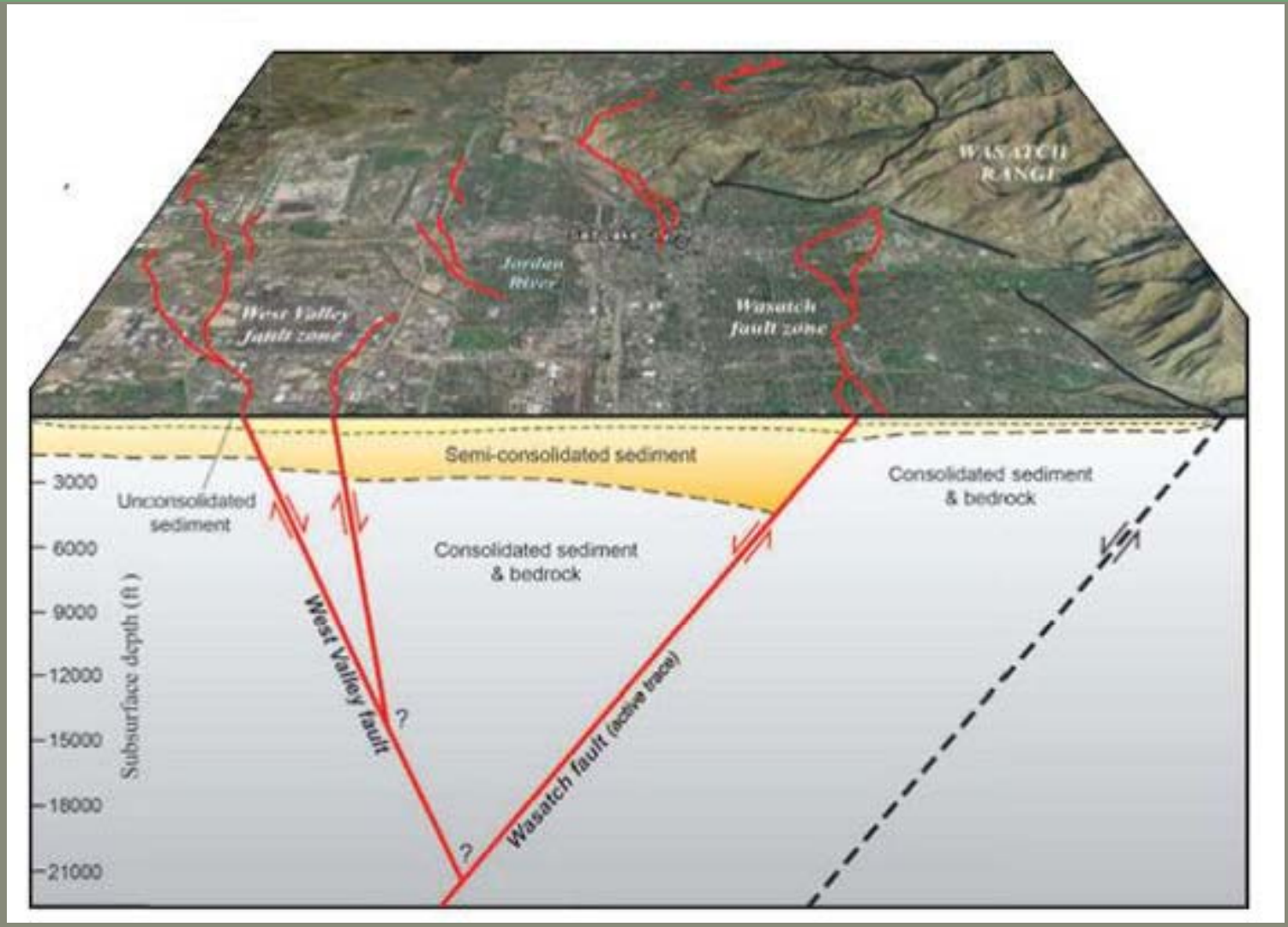
Wasatch Fault – Salt Lake City Segment



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Wasatch Fault at Little Cottonwood Canyon

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Normal Fault Offset – Typical Examples

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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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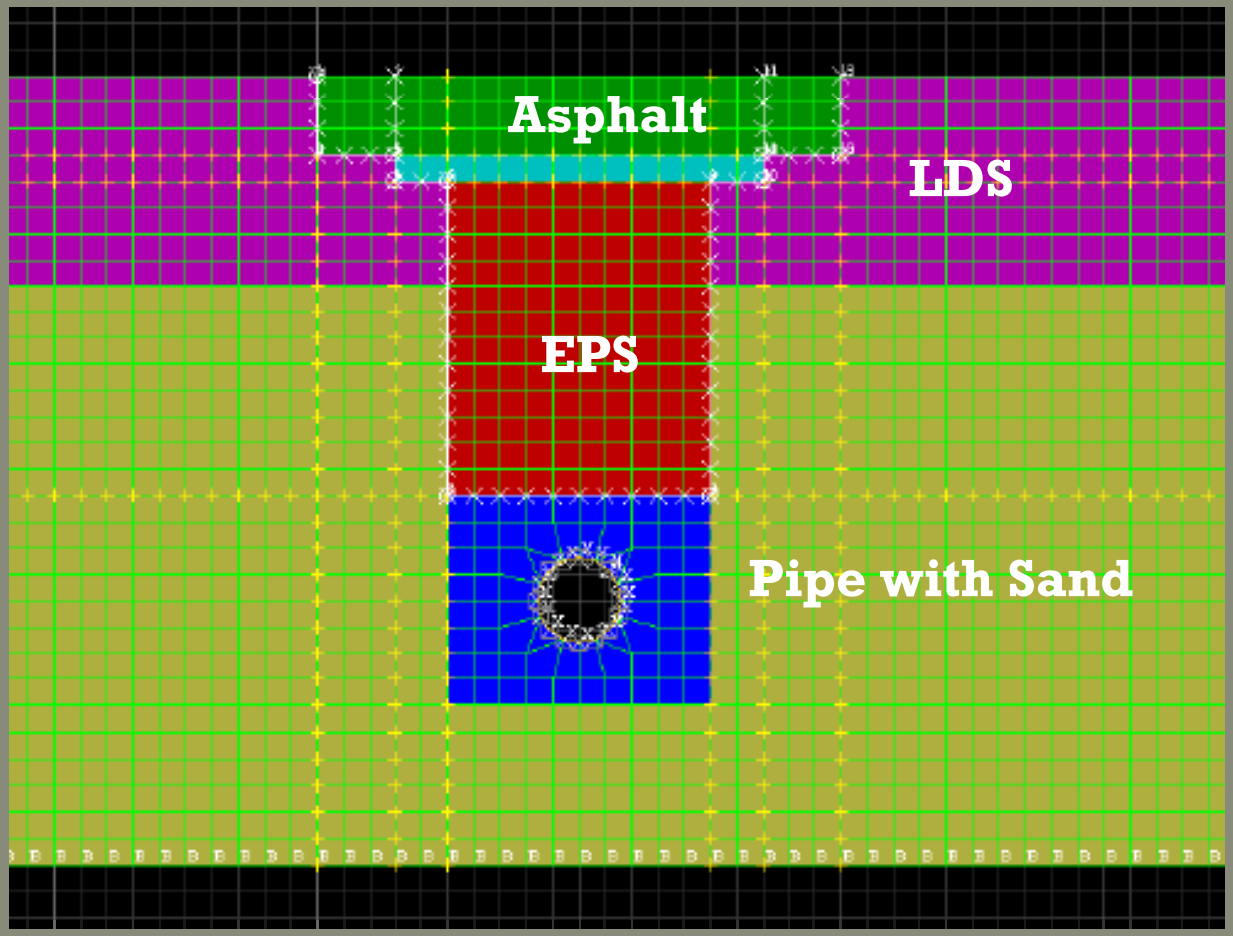
Pipelines (Light-weight Cover Over Normal Faults)



Lightweight-Cover System
(X-sectional View)

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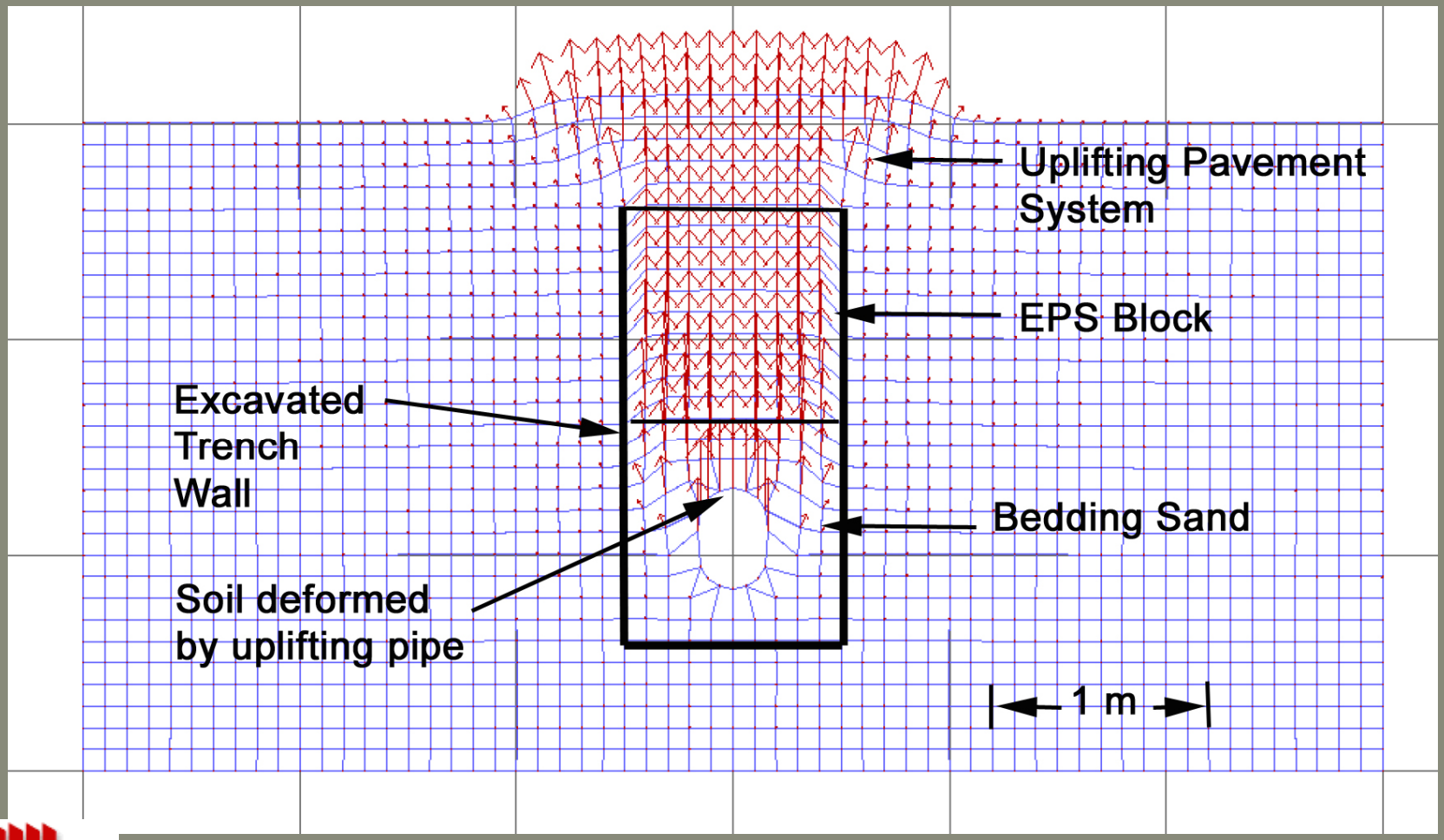
Pipelines (Light-weight Cover Over Normal Faults)



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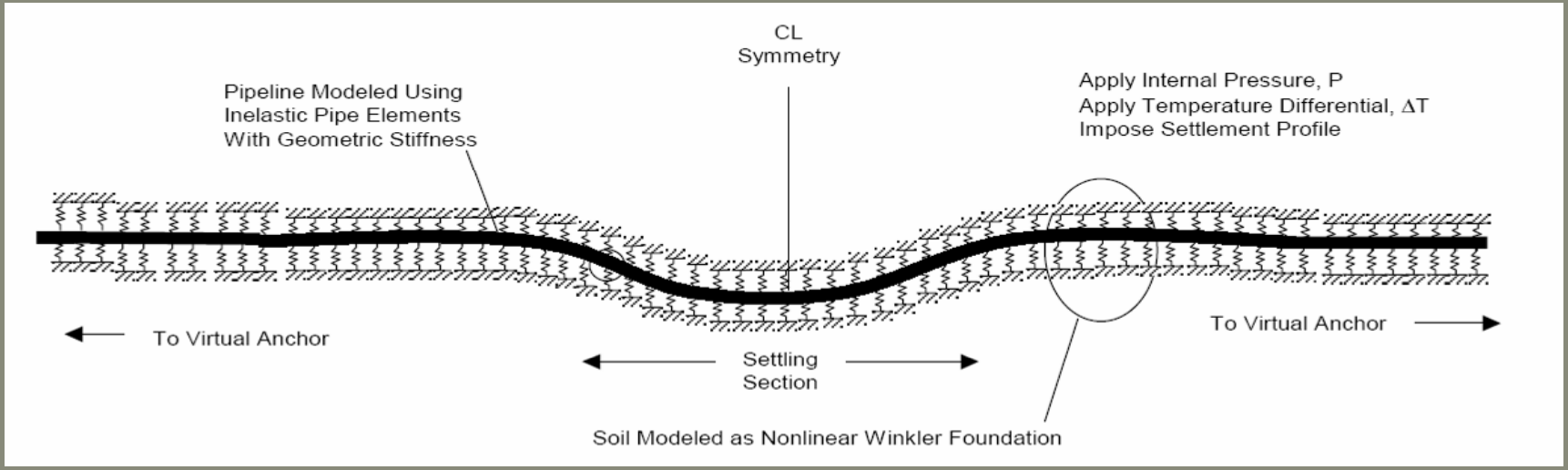
Displacement Vectors During Failure

Development of Soil Springs for Numerical Modeling



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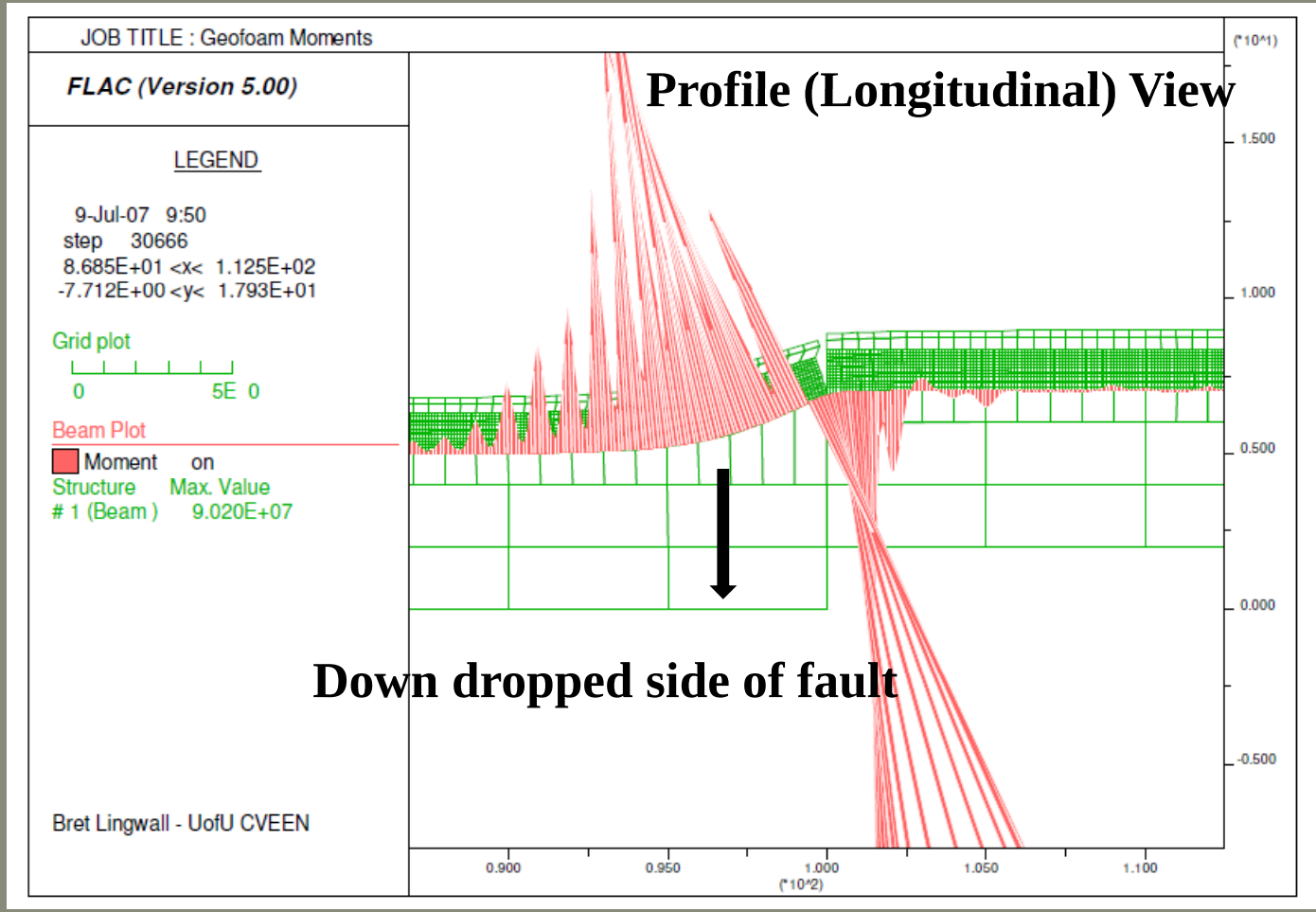

Bending Moments in Pipe from 2 m offset

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Construction of Uplift Tests

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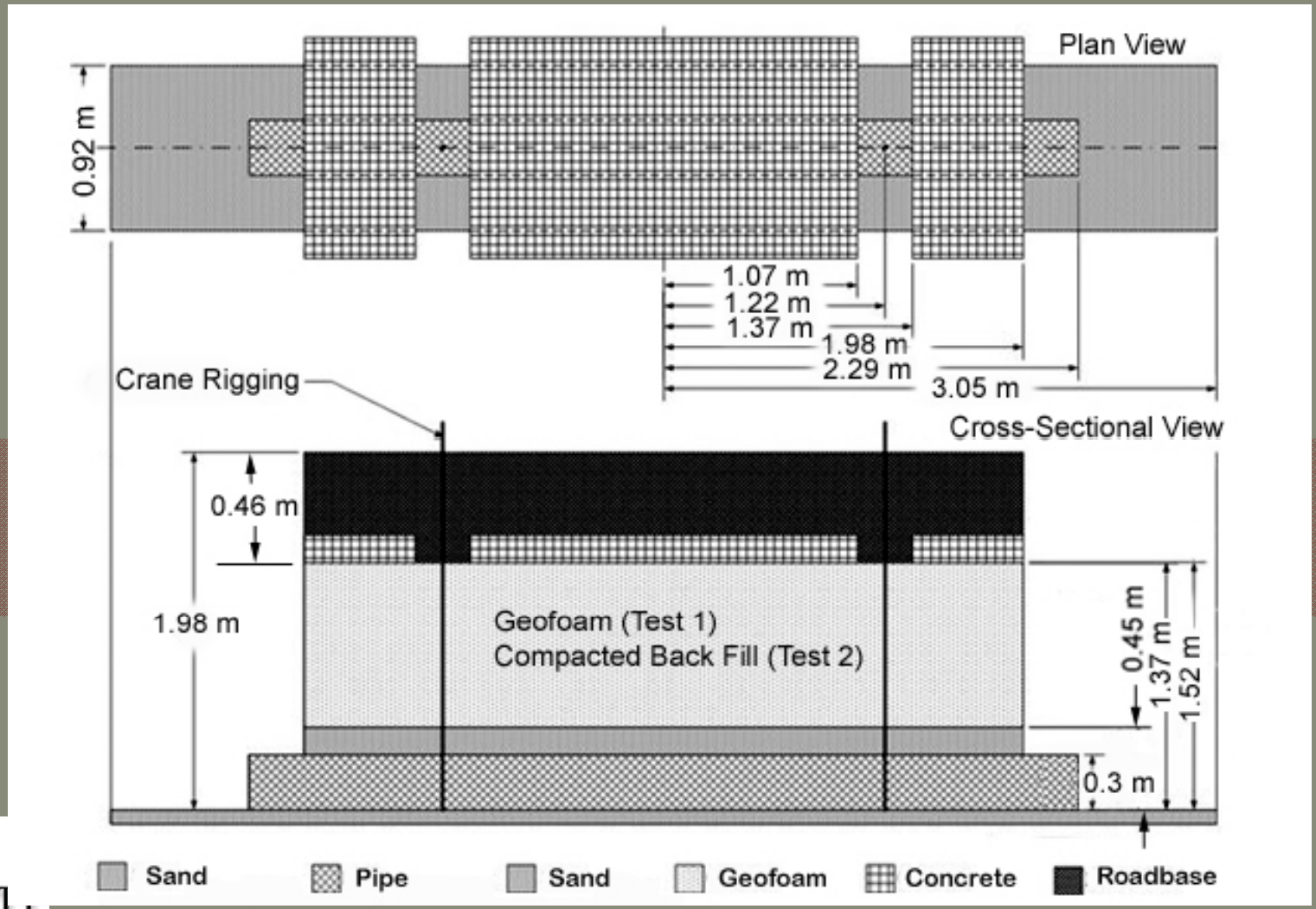
Lift-up Test Layout



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Vertical Uplift Tests

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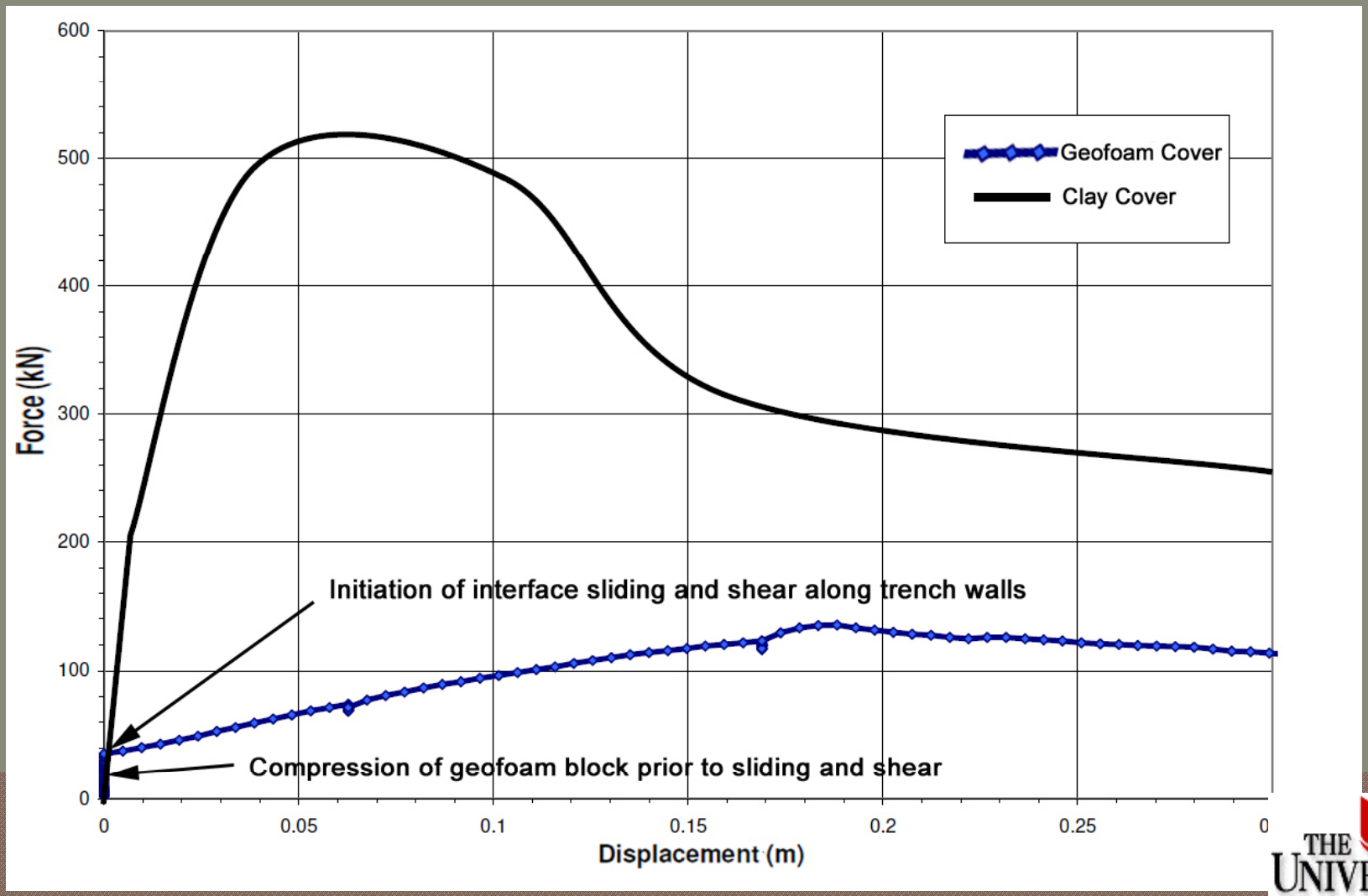
Force-Displacement Curves from Uplift Tests



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Pipelines (Light-weight Cover Over Faults)

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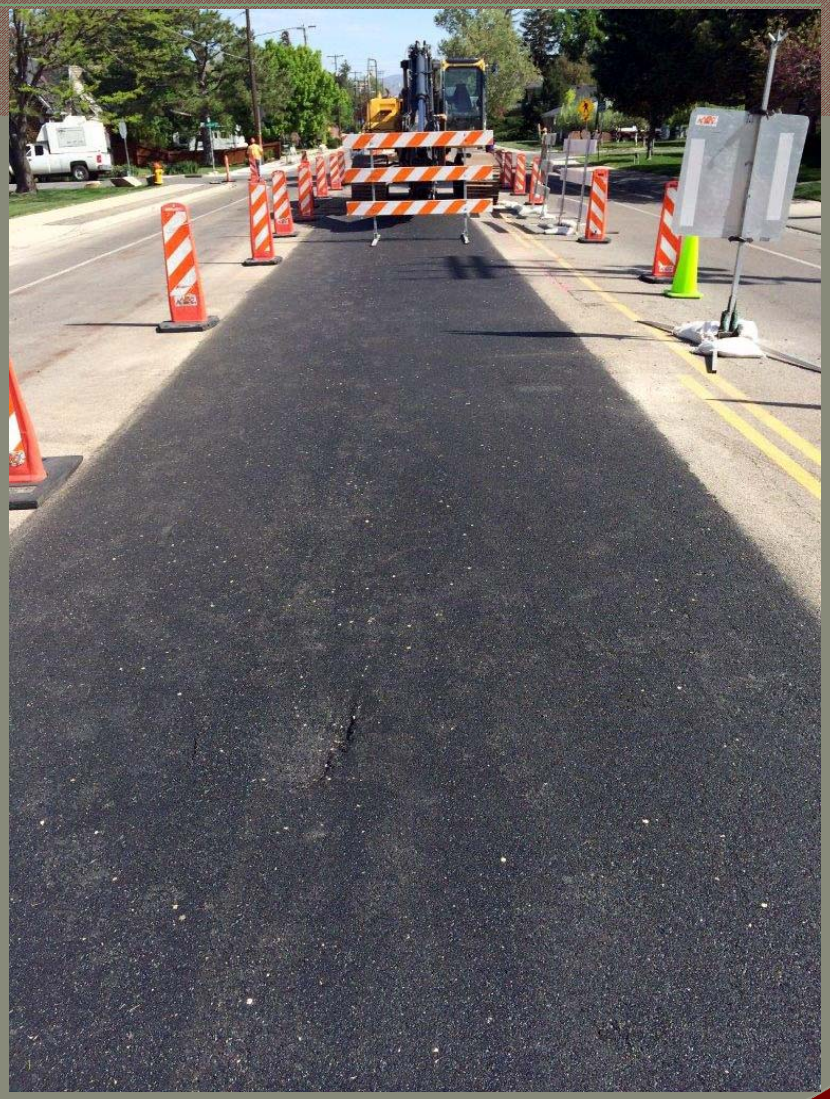
Pipelines (Light-weight Cover Over Faults



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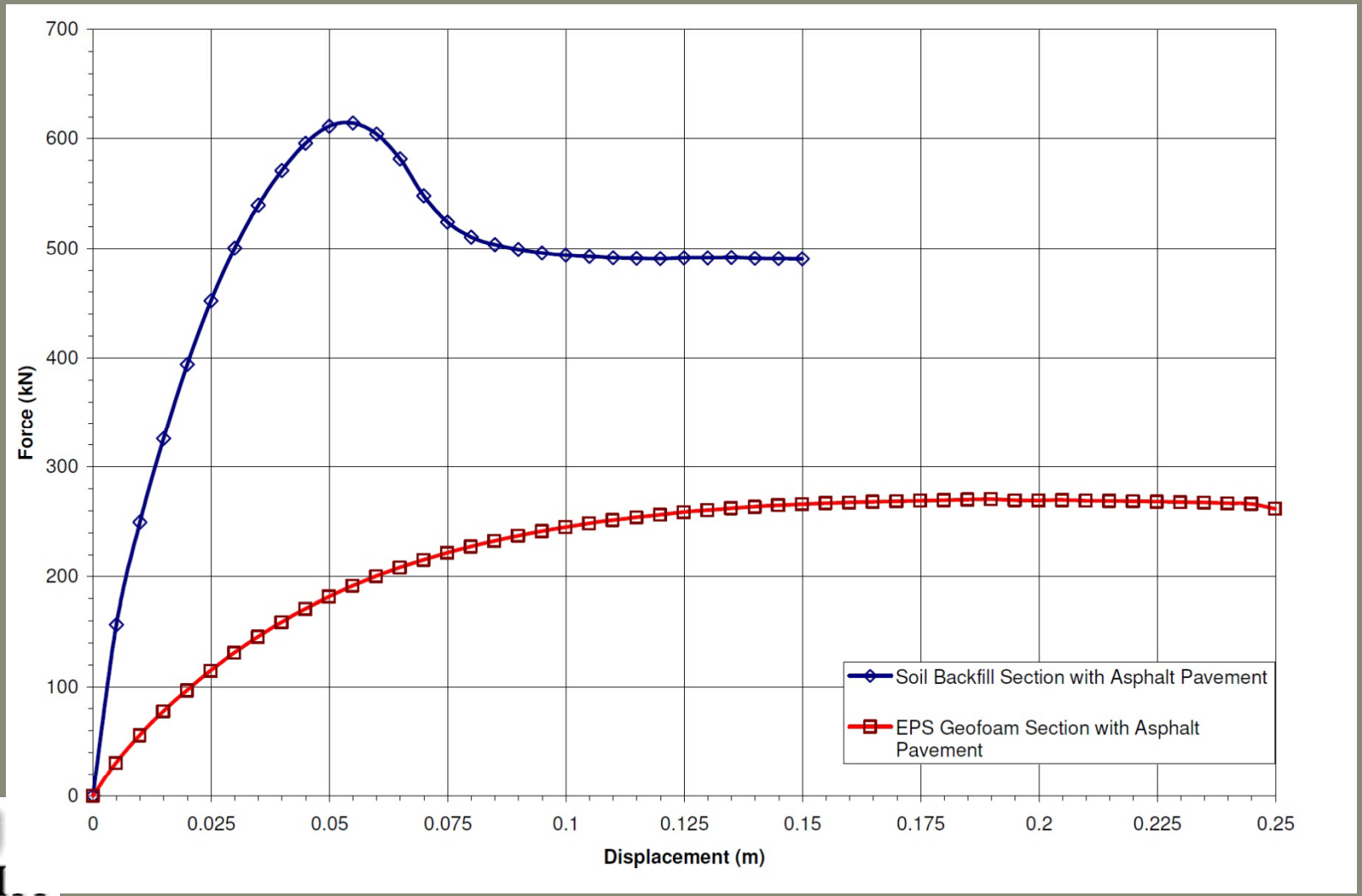
Results of Numerical Modeling of Cover with Asphalt



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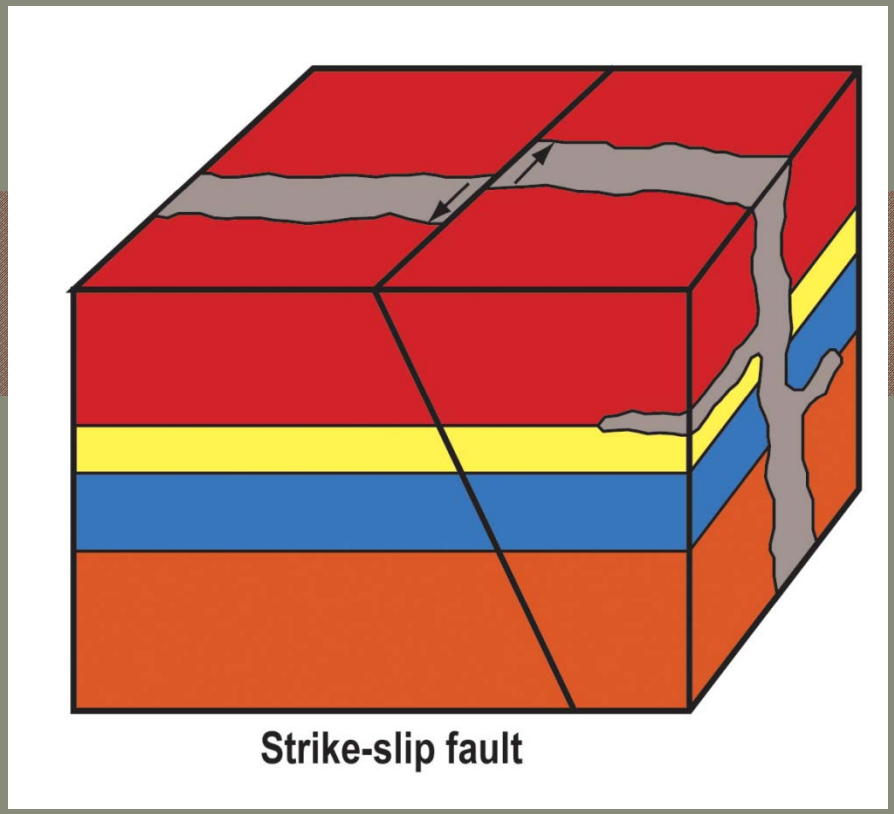
Horizontal Displacement from Strike Slipe Faults



Strike-slip fault

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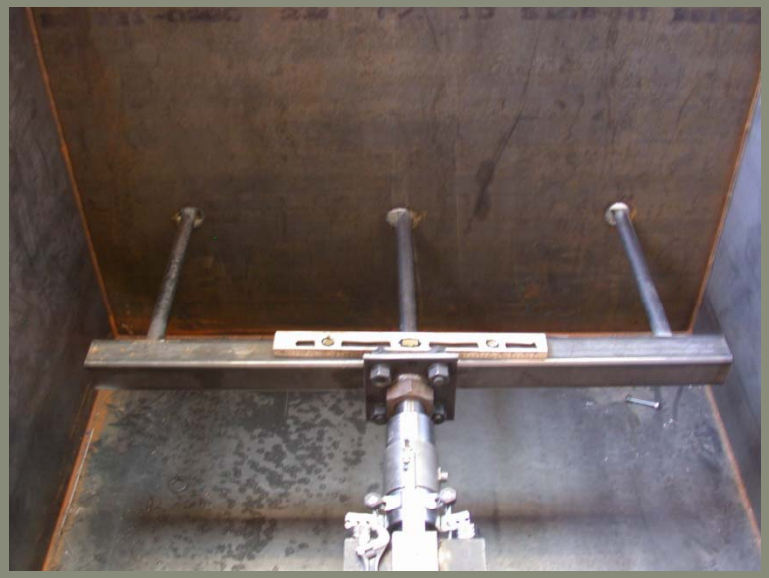
Horizontal Offset from Permanent Ground Displacement



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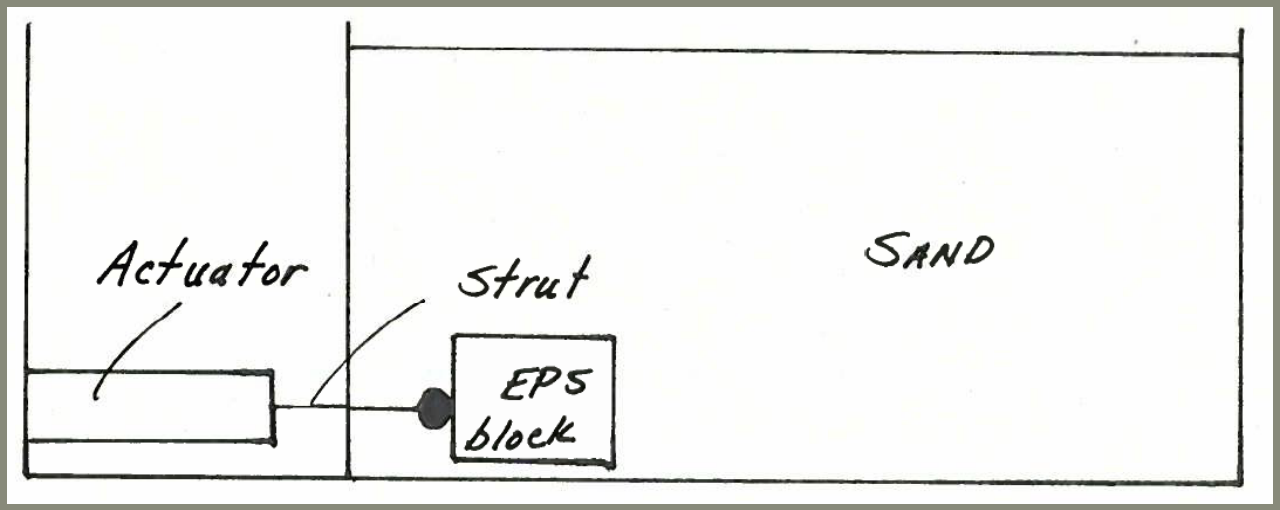
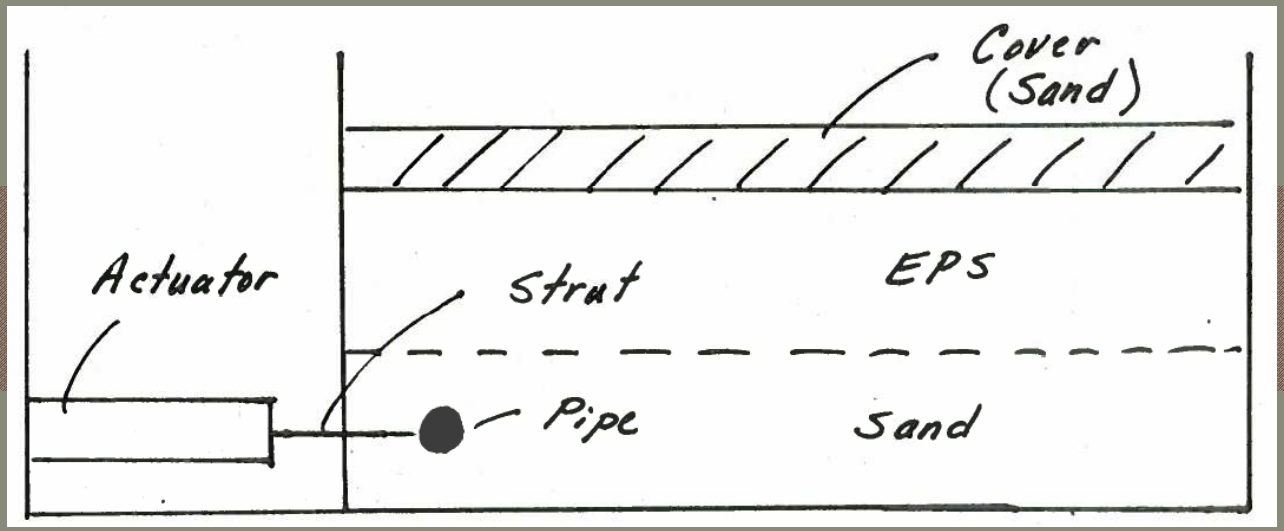
Horizontal Offset from Permanent Ground Displacement





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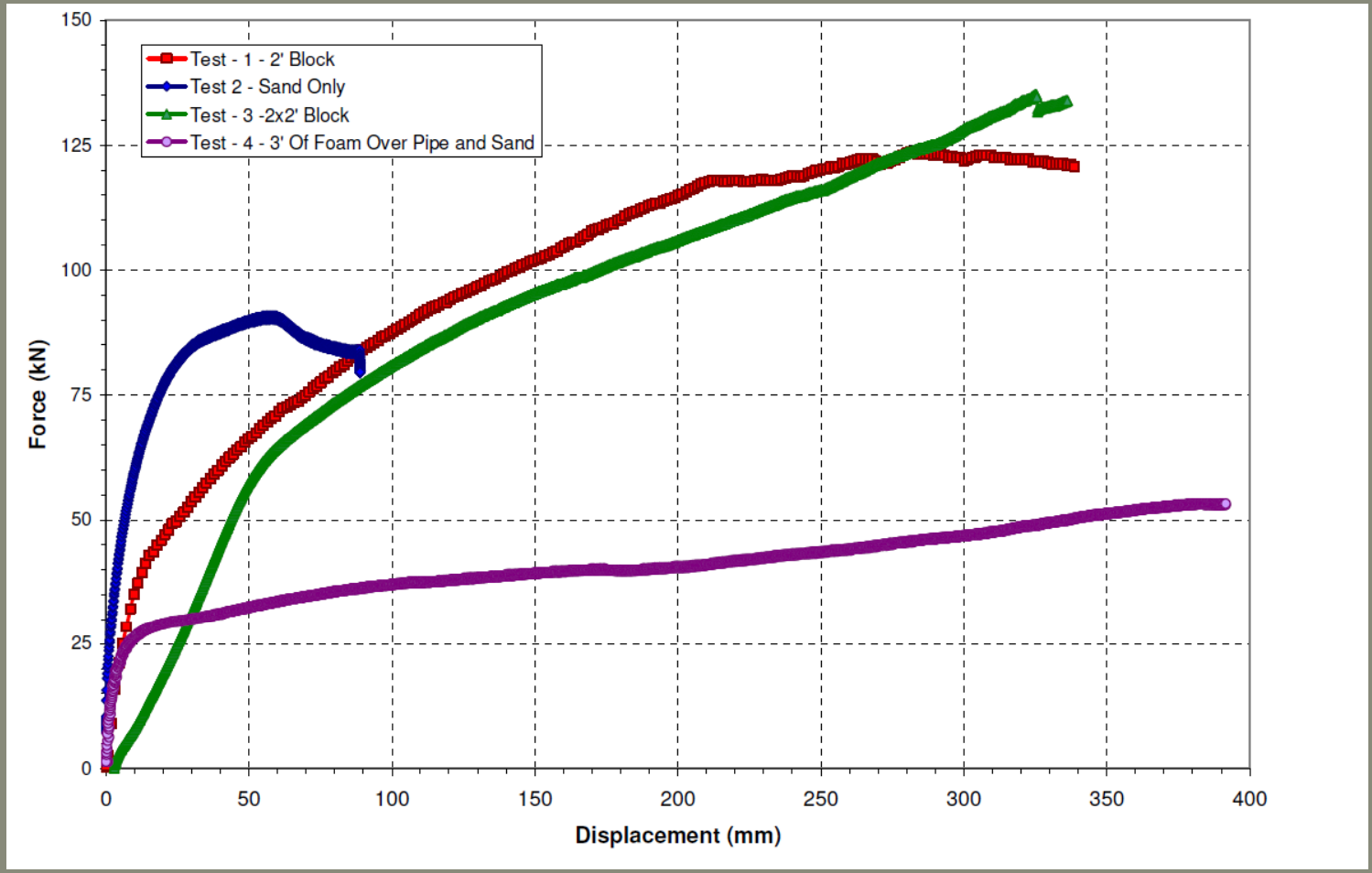
Horizontal Offset from Permanent Ground Displacement



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