Passive Force-Displacement Response from Large Scale Pile Cap Tests

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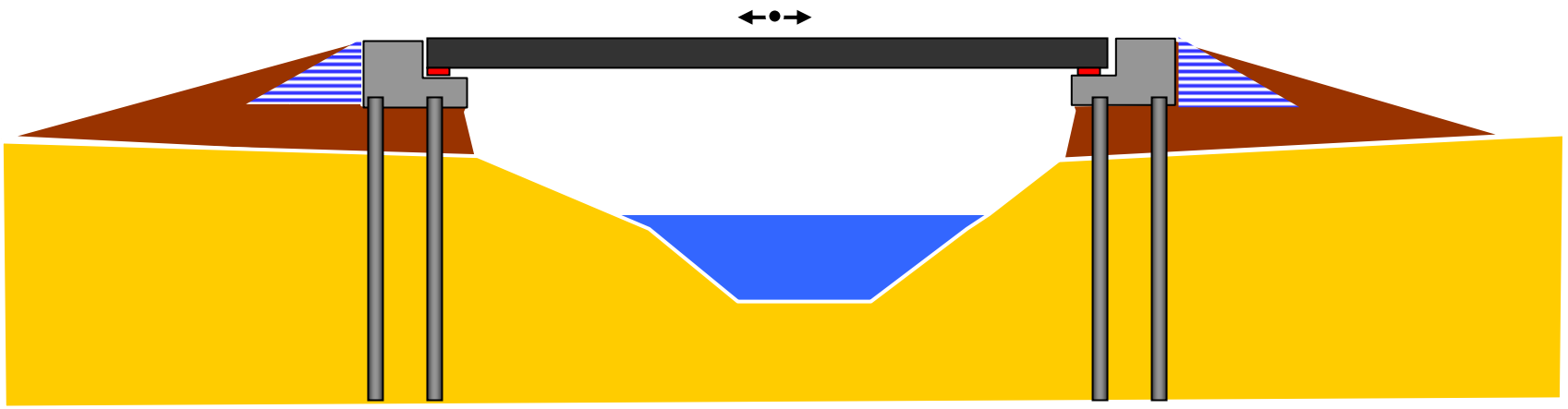
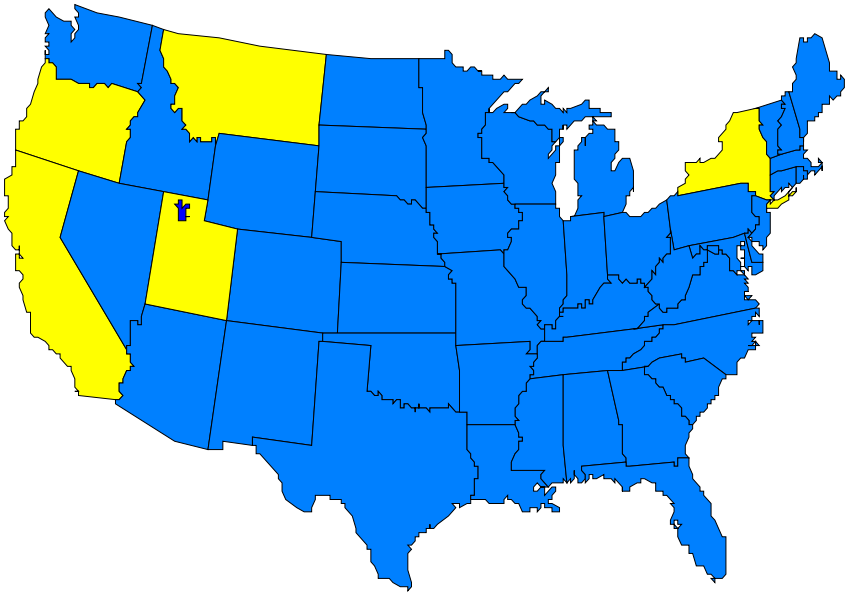
Passive Force on Bridge Abutments



- Ultimate passive force significant in seismic bridge response.
- Passive force-deflection relationship (Stiffness) also important

Passive Force Testing-Sponsors

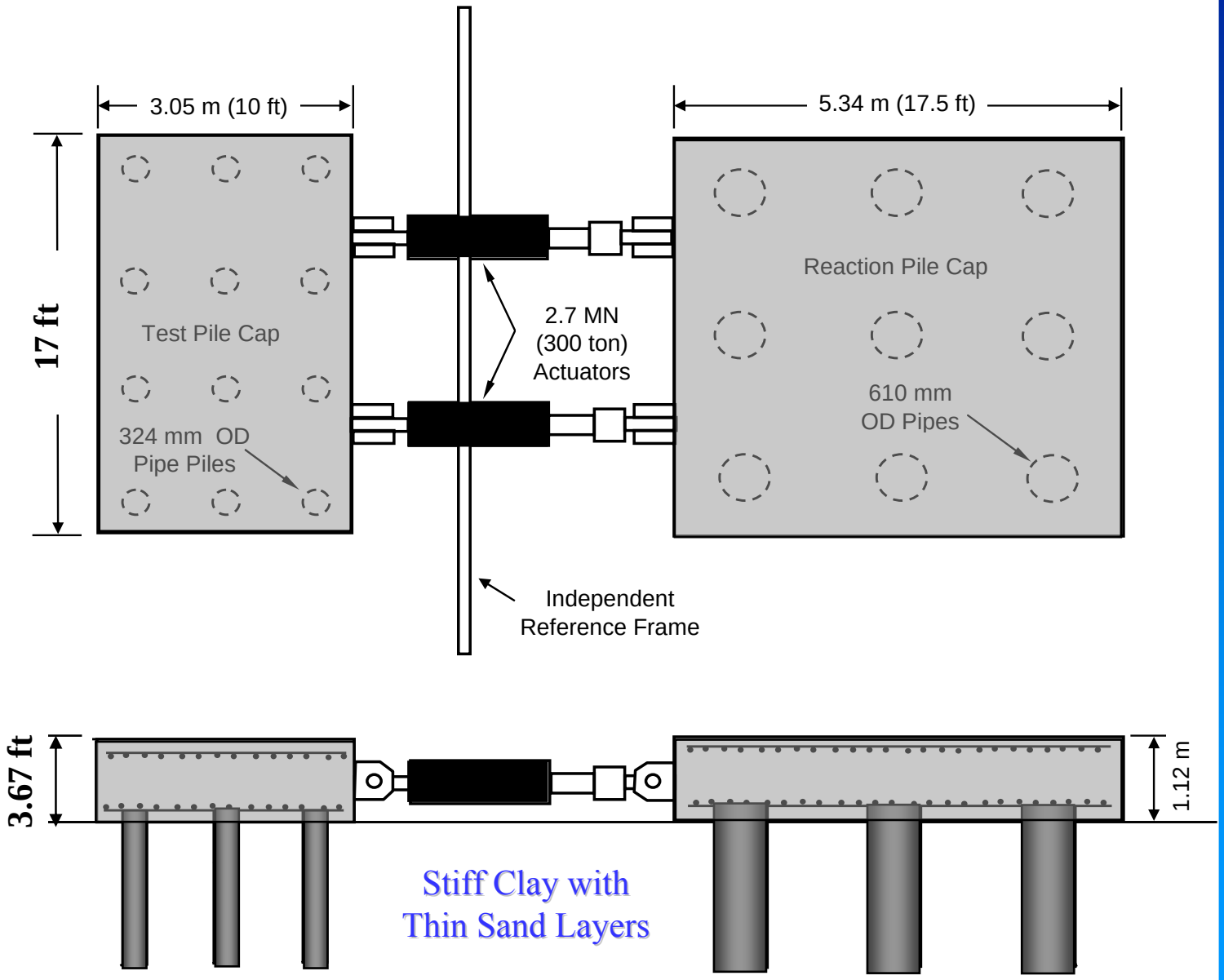
- Utah DOT - FHWA
- Caltrans
- Oregon DOT
- Montana DOT
- New York DOT
- NSF-NEESR



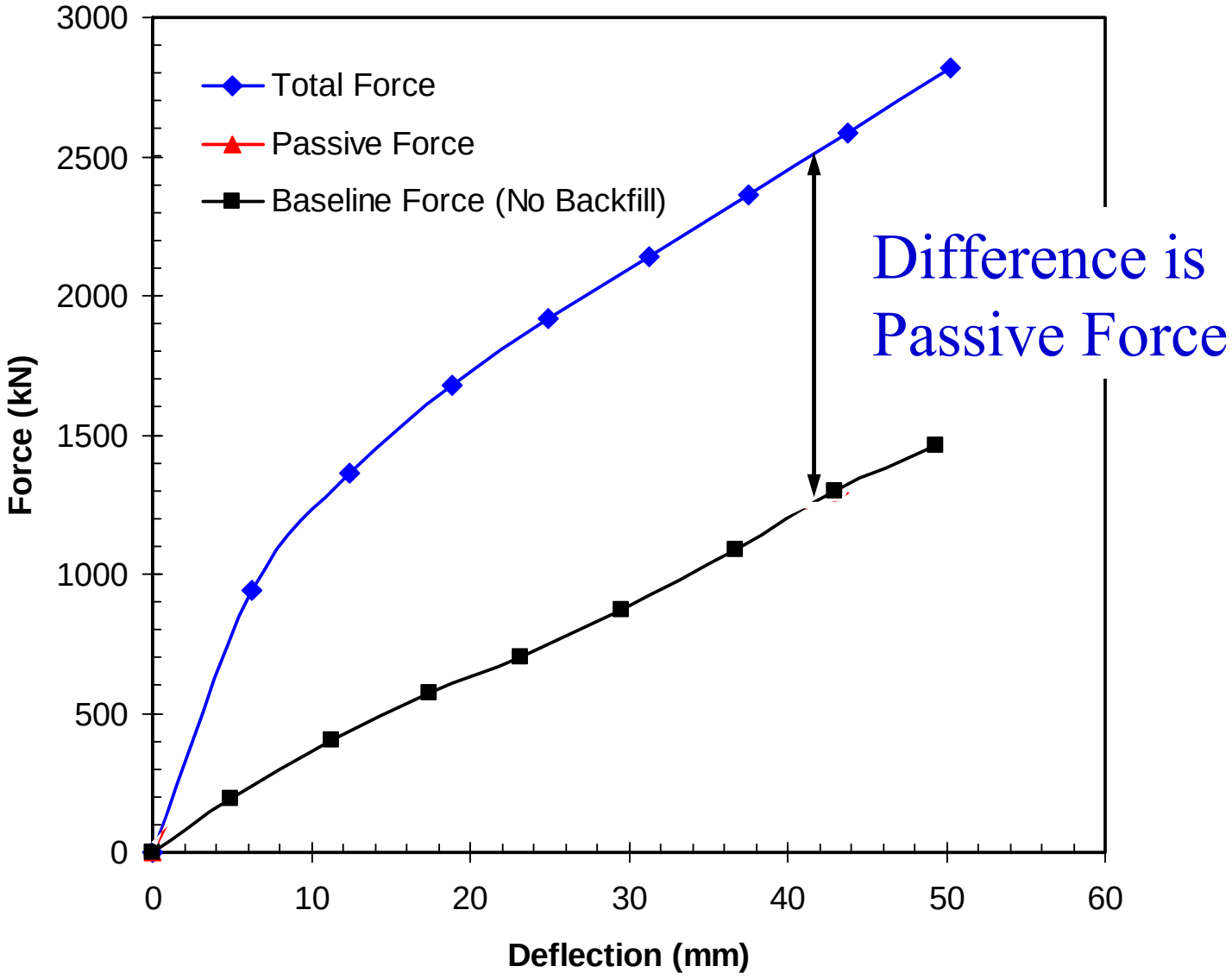
Passive Force Testing

- BYU has performed 12 large-scale passive force tests in past 12 years
  - Various Soil Types (Sand, Silty Sand, Gravels)
  - Various Geometries (3.7 ft high, 5.5 ft high)
  - MSE Wingwalls
  - Limited Width Gravel Zones
  - Dynamic & Static Loading

Pile Cap Geometry



Determination of Passive Force



Measured & Computed Ultimate Passive Force

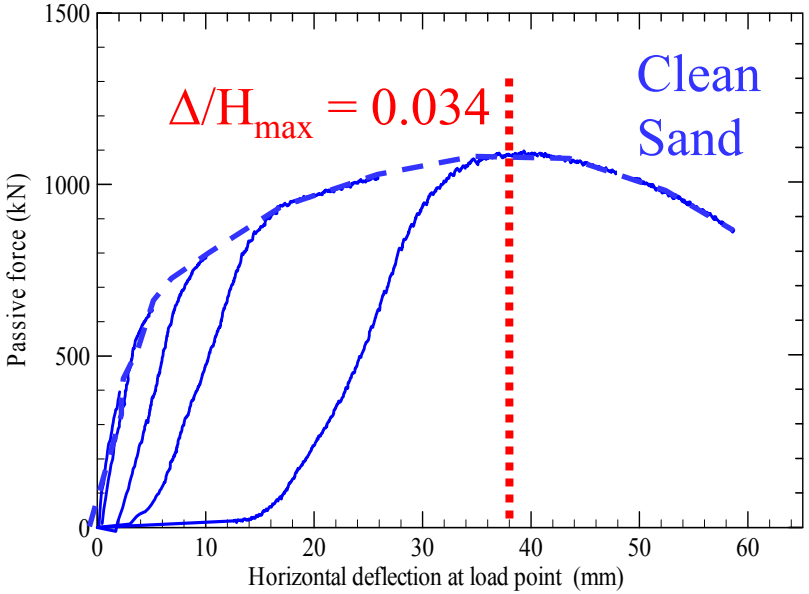
Method	Sand	Fine Gravel	Coarse Gravel	Silty Sand
Measured	1090	774	1997	1428
Log Spiral	922	817	1688	1210
Caltrans	914	914	914	914
Coulomb	1577	1149	3464	1575
Rankine	357	405	719	804

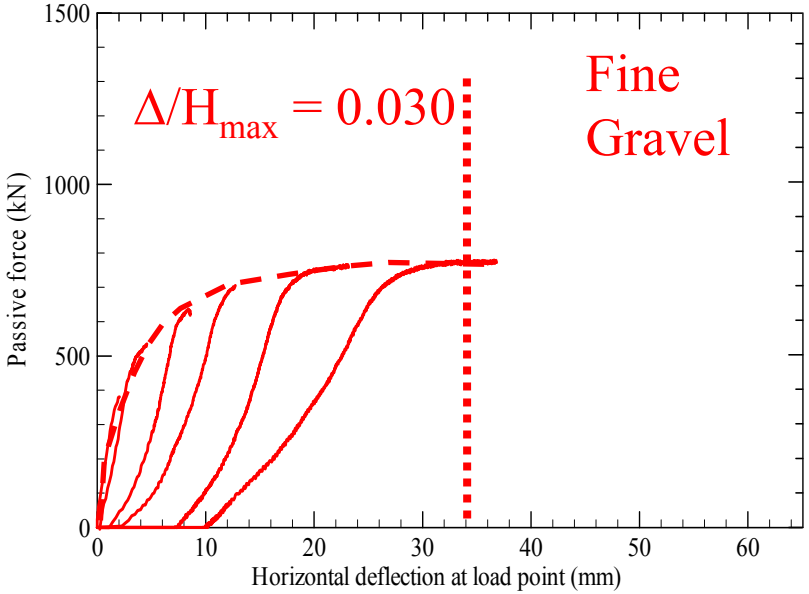
Note: Forces are in kN

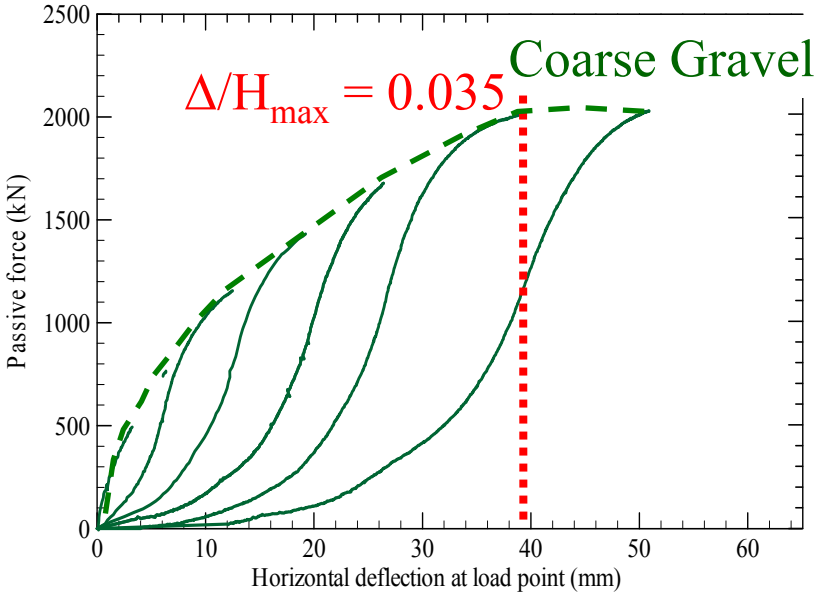
Log Spiral is typically within 25% of Measured

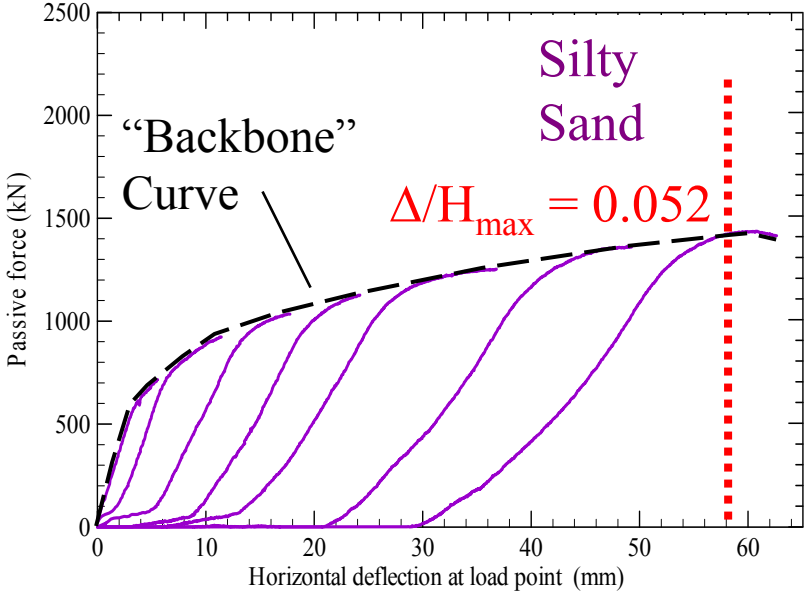
Nature likes log spirals!

Development of Passive Resistance







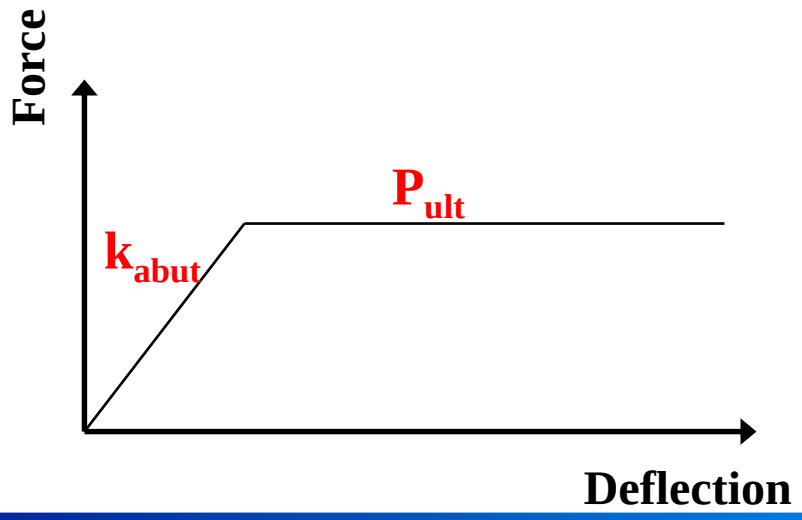


Bi-Linear Load-Deflection Curve

(Caltrans, 2004)

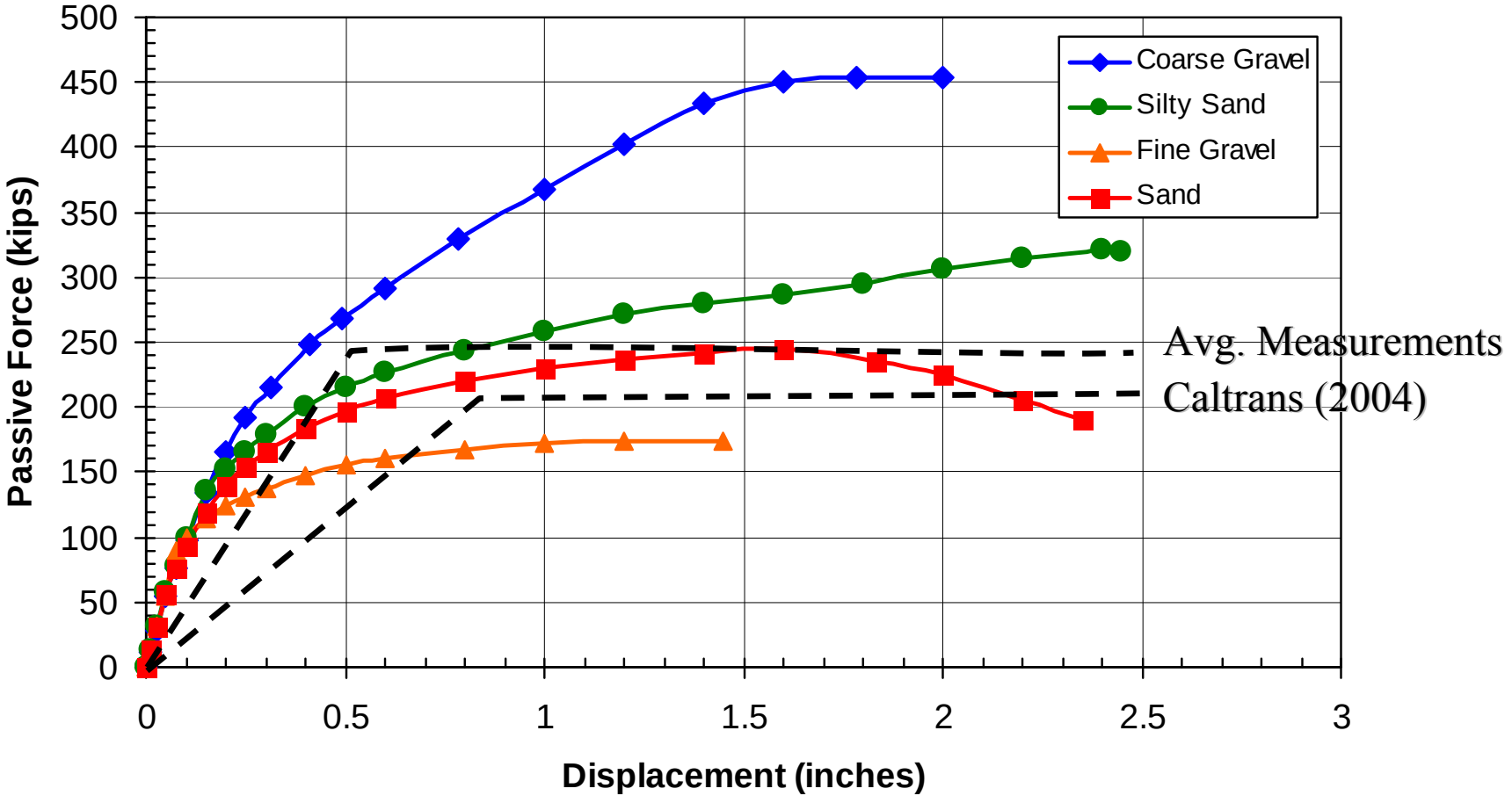
Ultimate resistance, P_{ult} = (5.0 ksf)*(H/5.5 ft)*A_{wall}

Initial resistance, k_{abut} = (20 kip/in)*(H/5.5 ft)*w

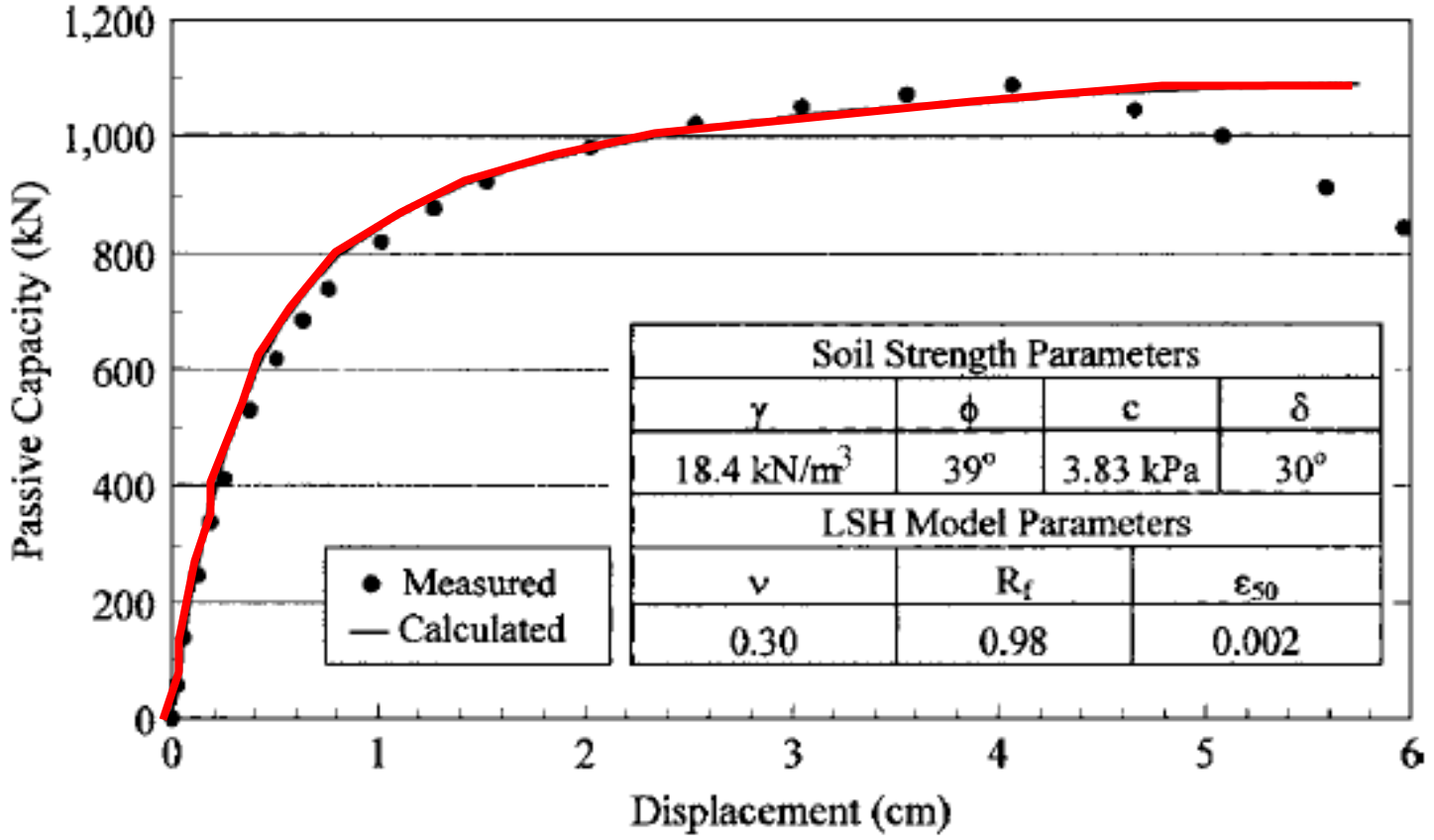


P_{ult} and stiffness based on UC-Davis load test on 5.5 ft abutment with silty clay backfill

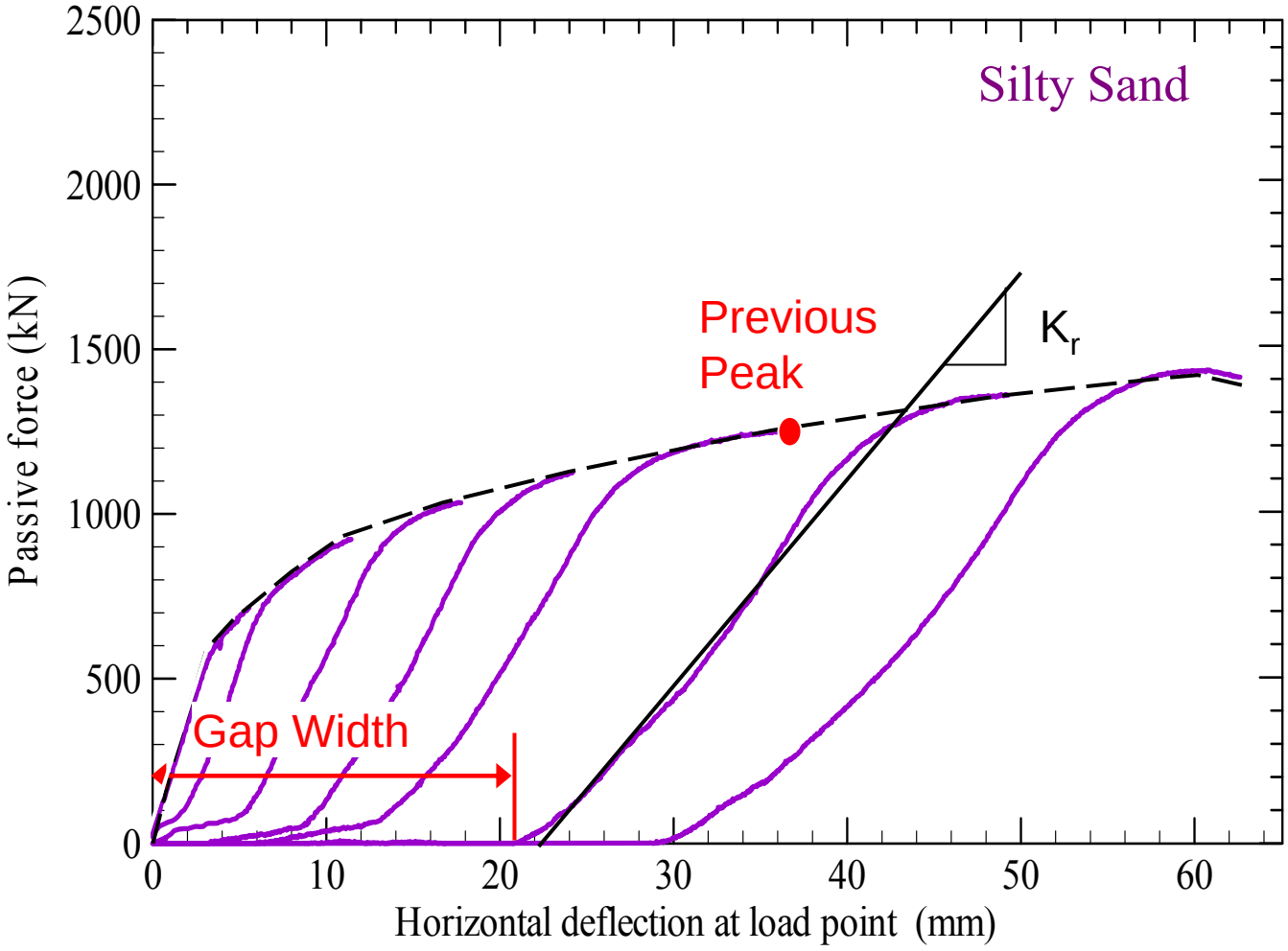
Comparison of Passive-Force Displacement Curves



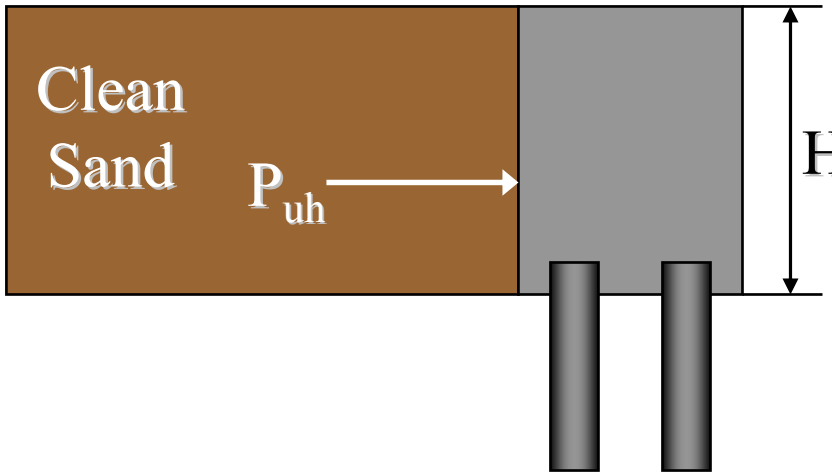
Passive Force-Deflection Curve using Log-Spiral Hyperbolic (LSH) method



Gaps and Reloading

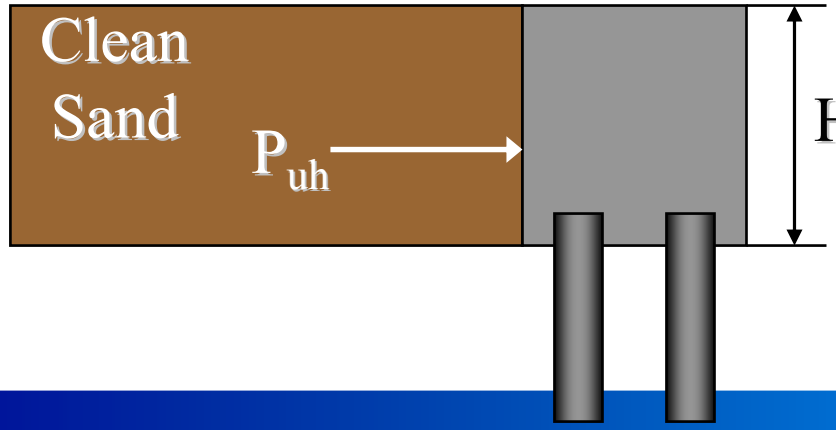


Effect of Wall Height



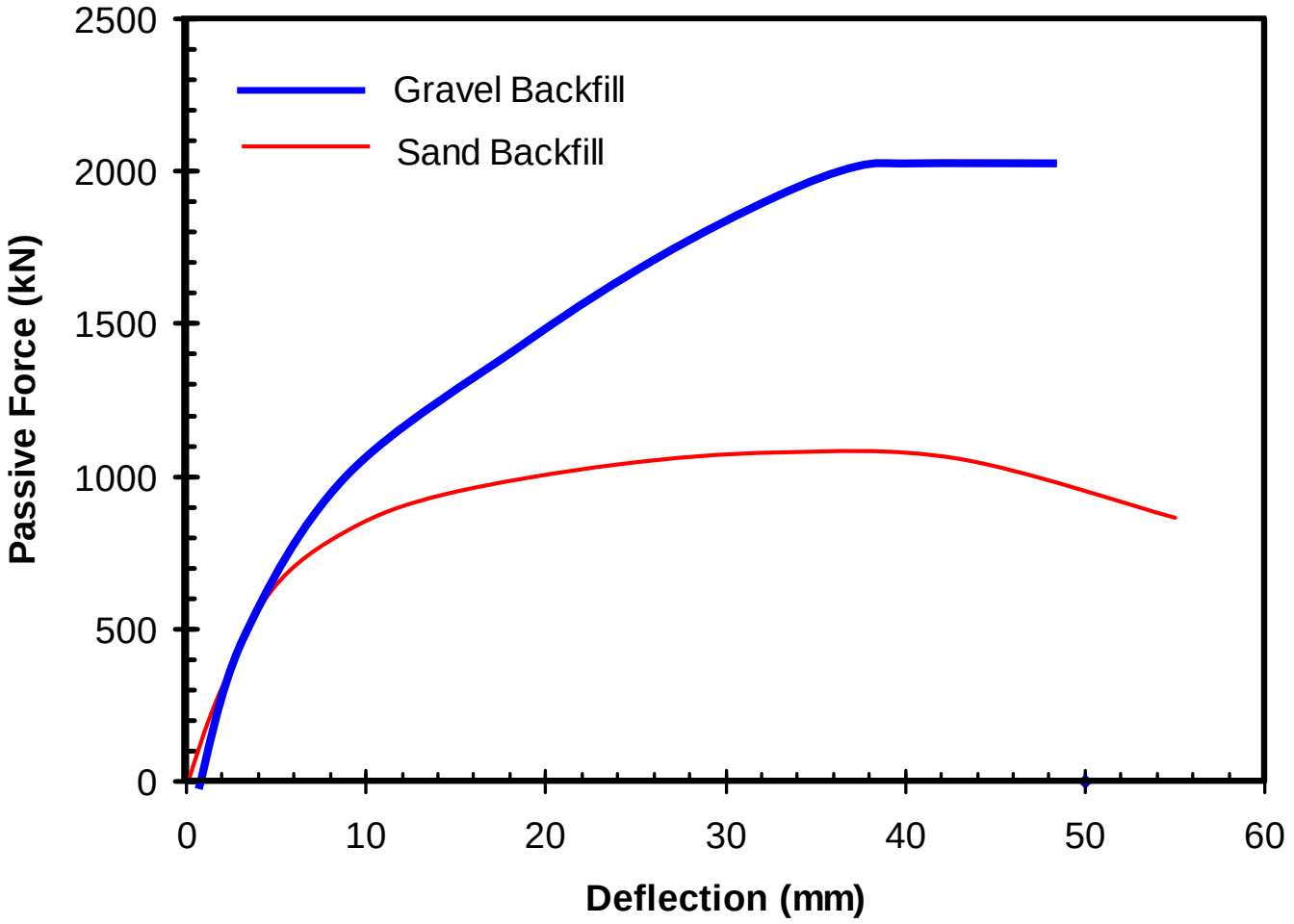
P_{uh} = 22 kips/ft of width

$22/10.6 \approx (5.5/3.67)^2$

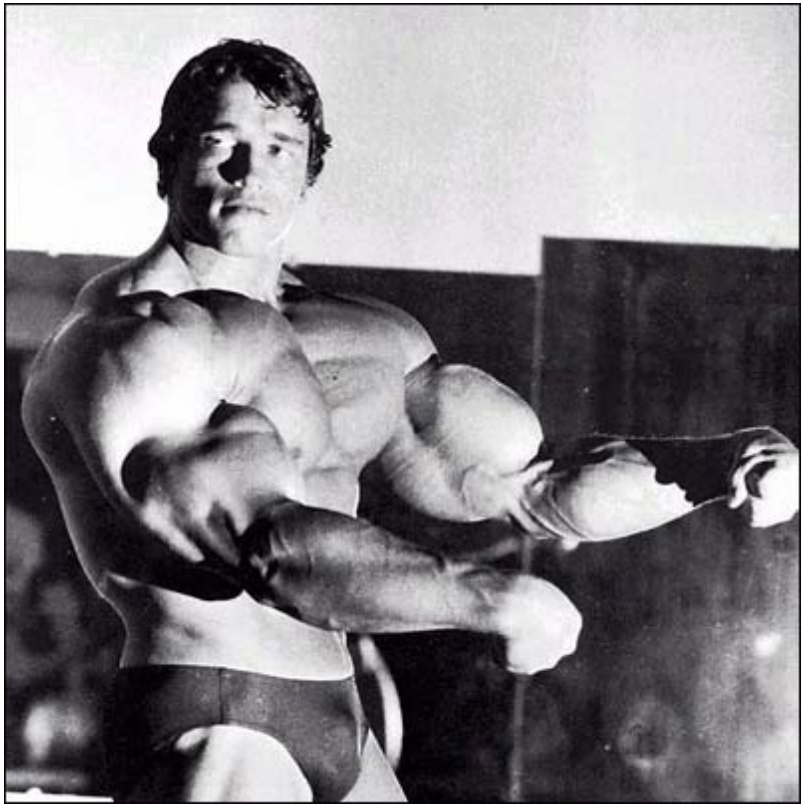


P_{uh} = 10.6 kips/ft of width

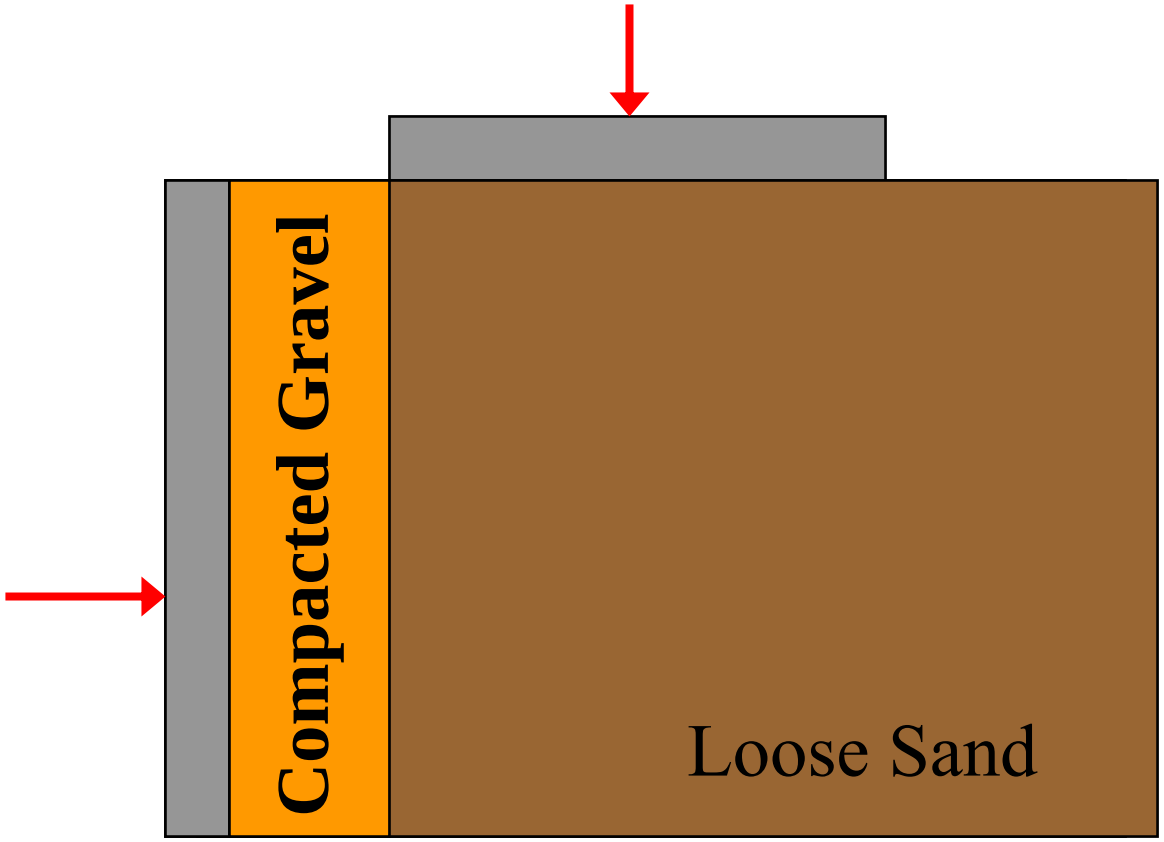
Passive Force for Gravel & Sand Backfills



How can we “pump up” the capacity of these abutments?

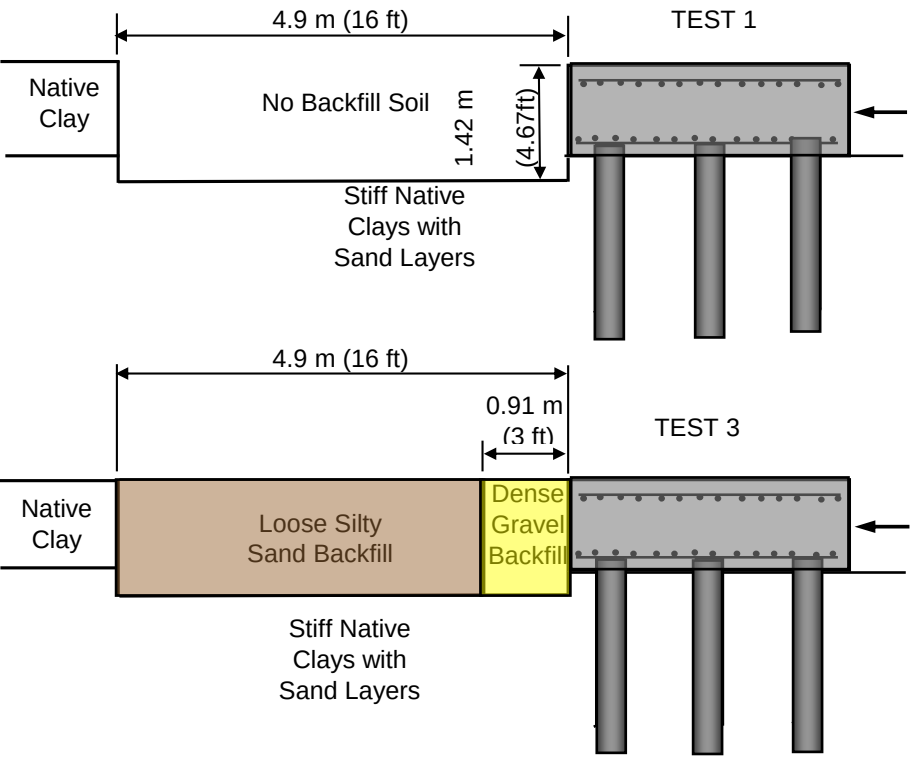


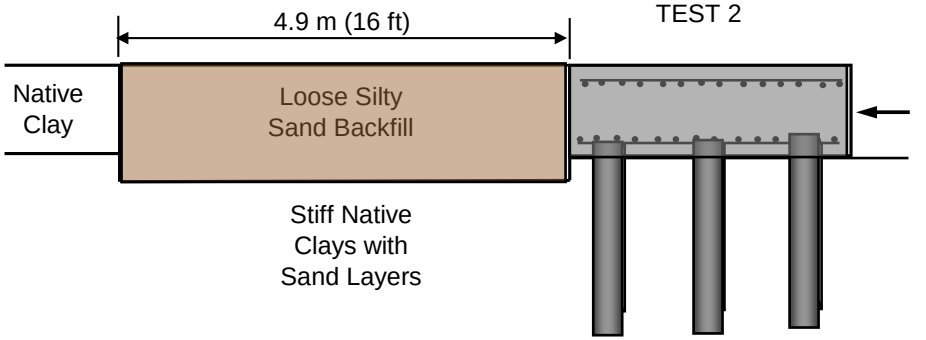
Compacted Gravel for Improved Foundation Performance

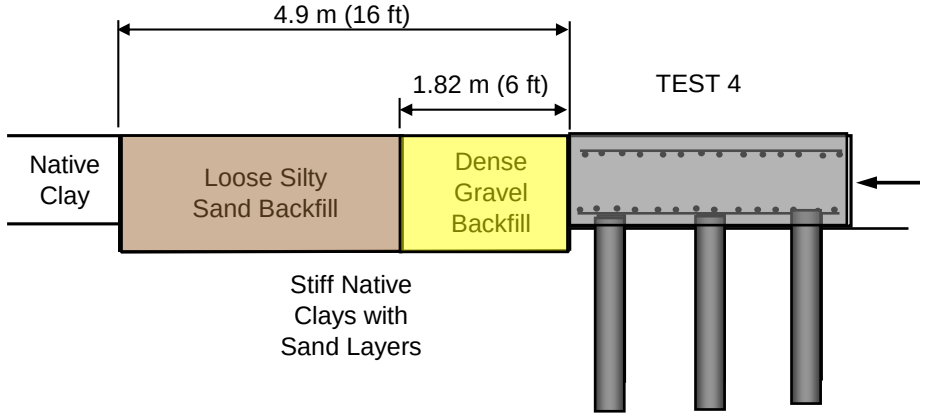


- Spreading of shear zones
- Reduction of stress on loose sand

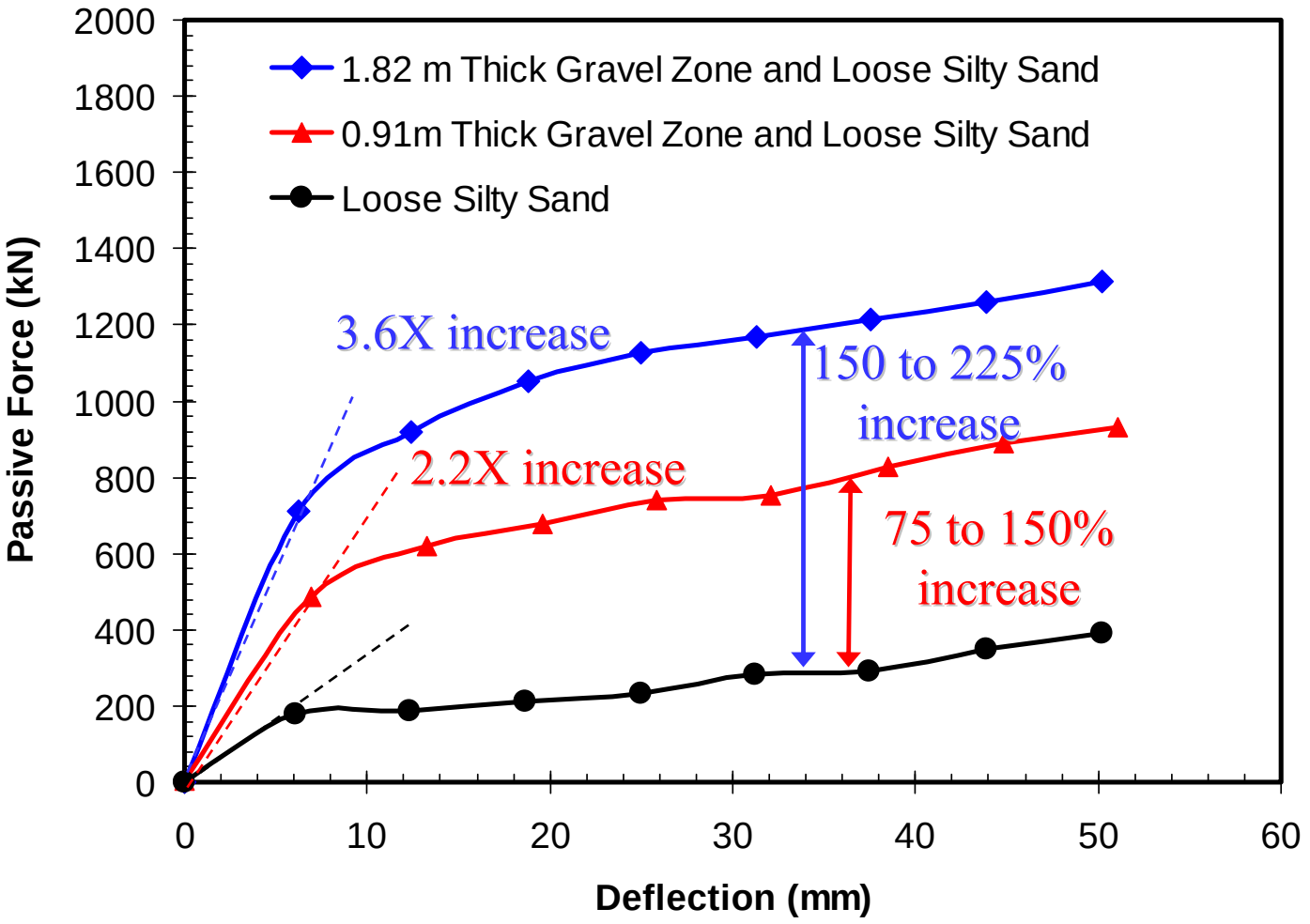
Backfill Geometry



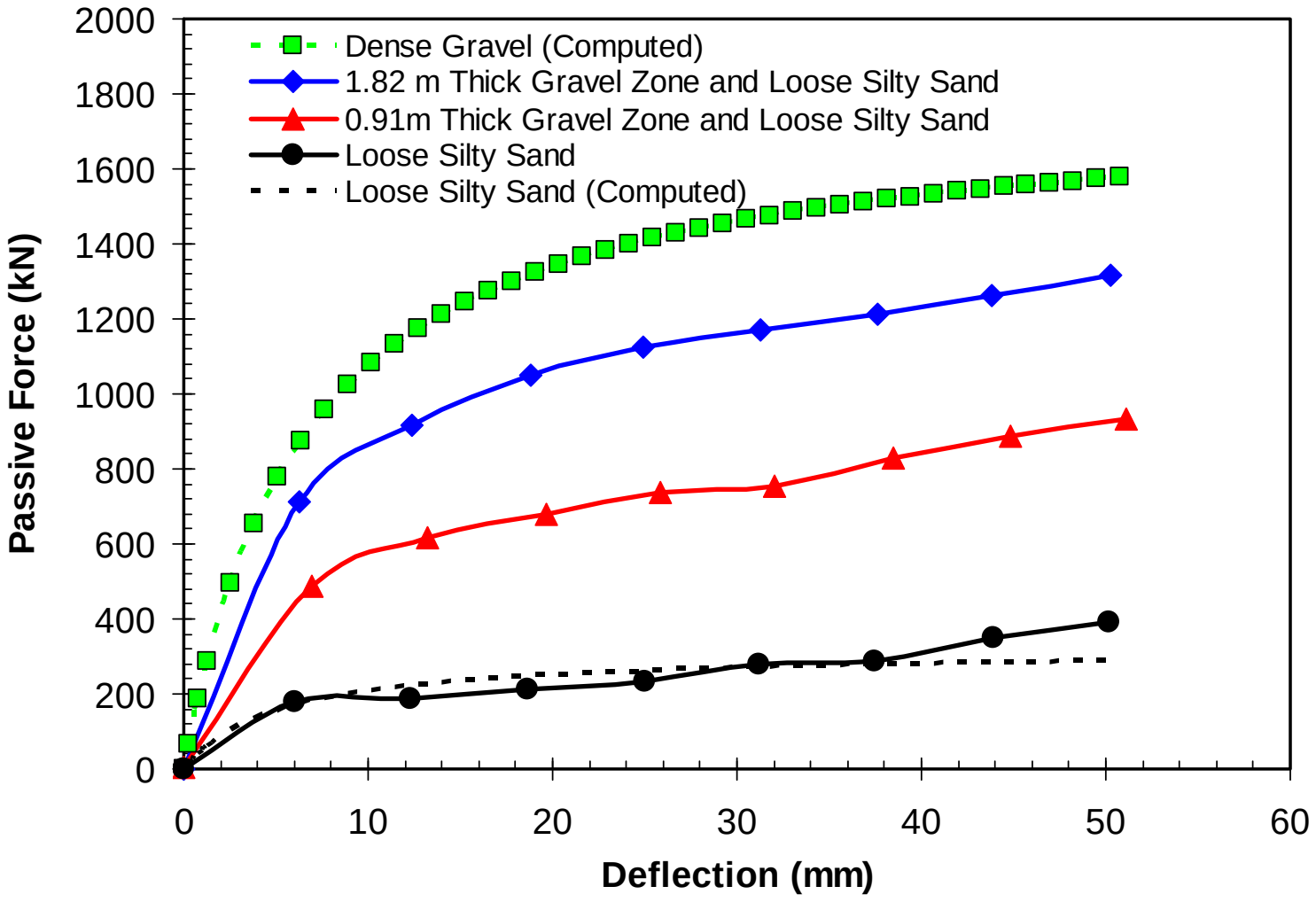




Passive Force-Deflection Curves



Passive Force-Deflection Curves

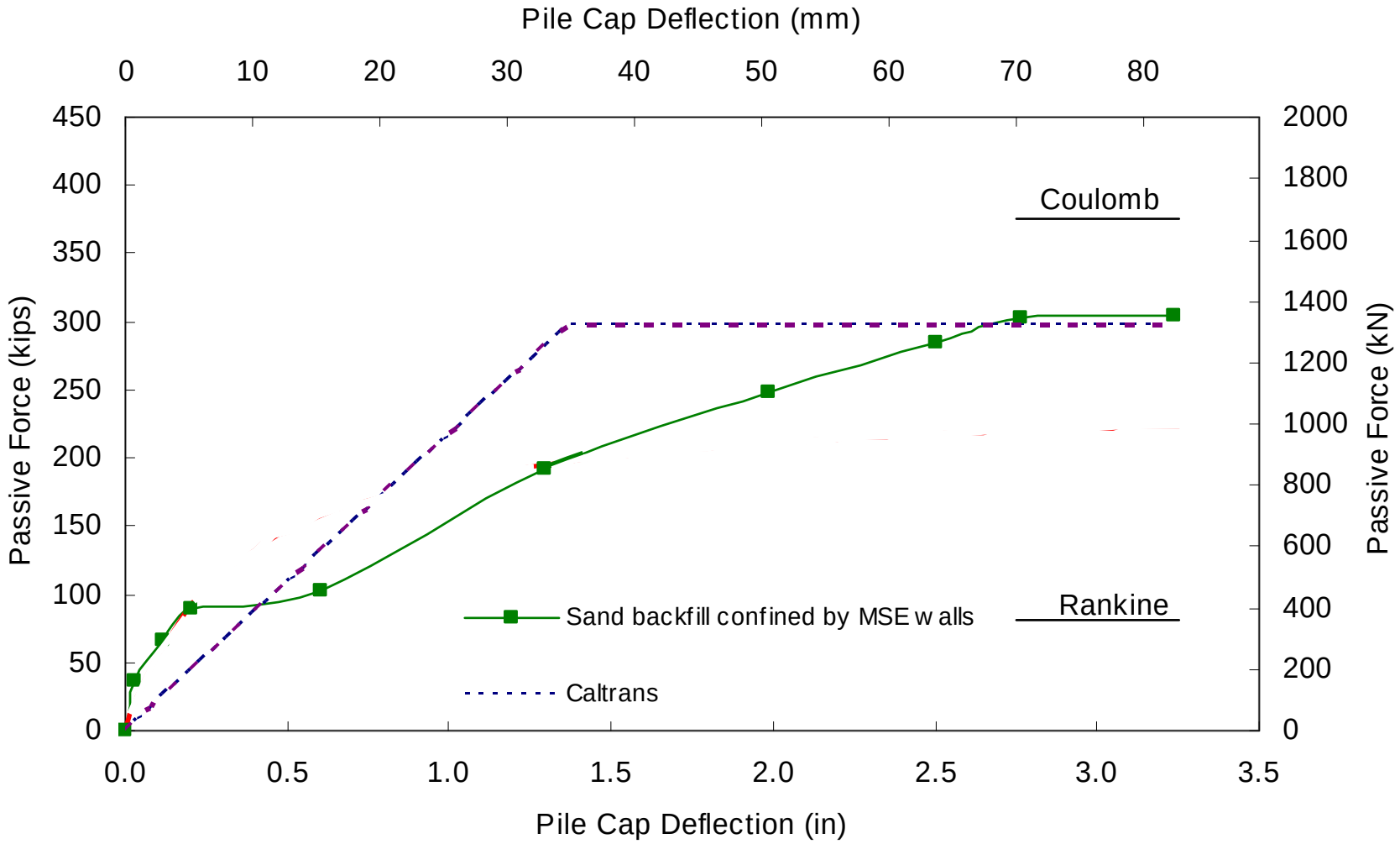


Abutments with MSE Wingwalls

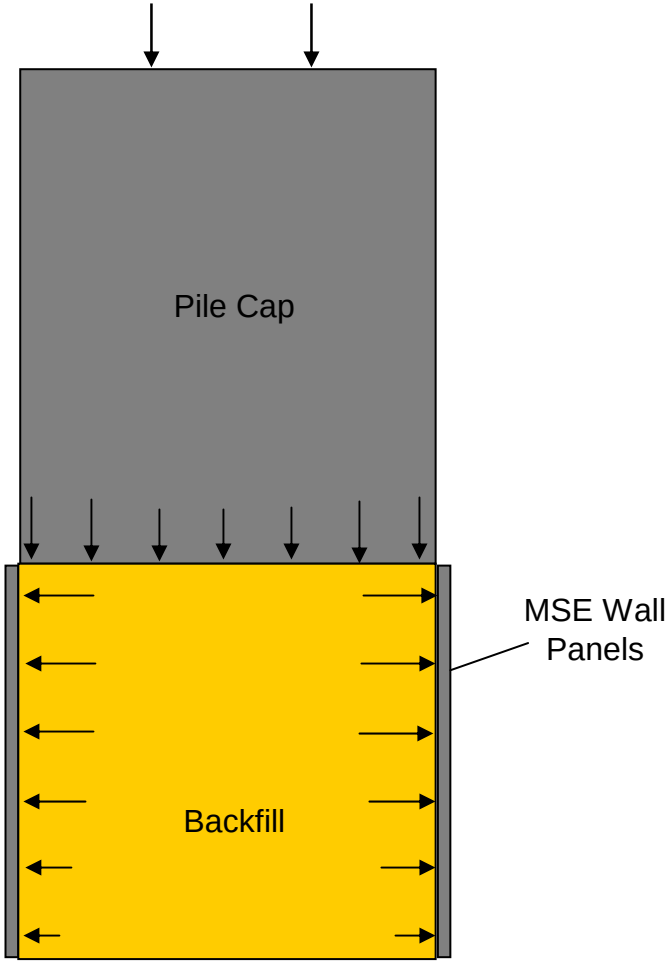
Load Test with MSE Wingwalls

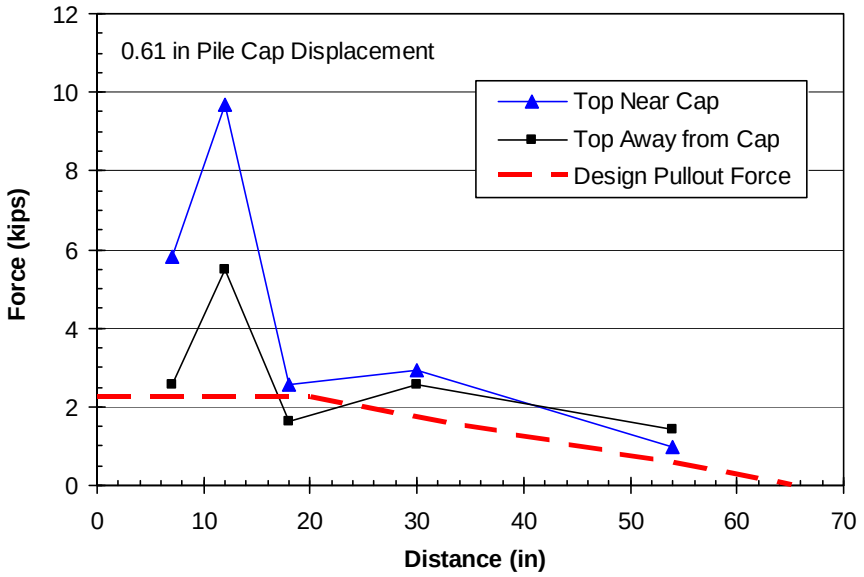
Load Test with MSE Wingwalls

Passive Force-Defection Curves (MSE)

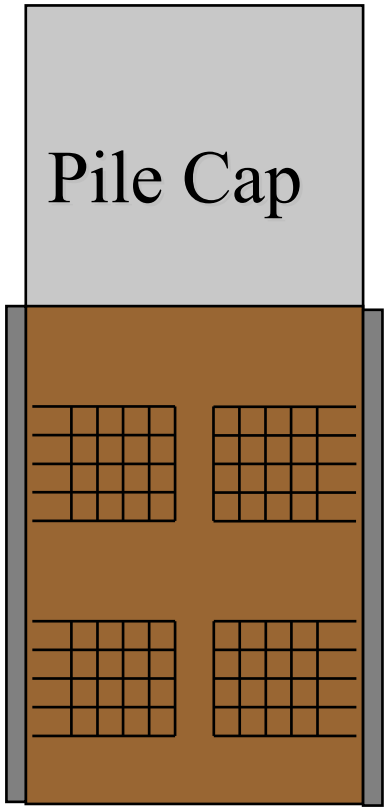


Reinforcement Pullout During Loading

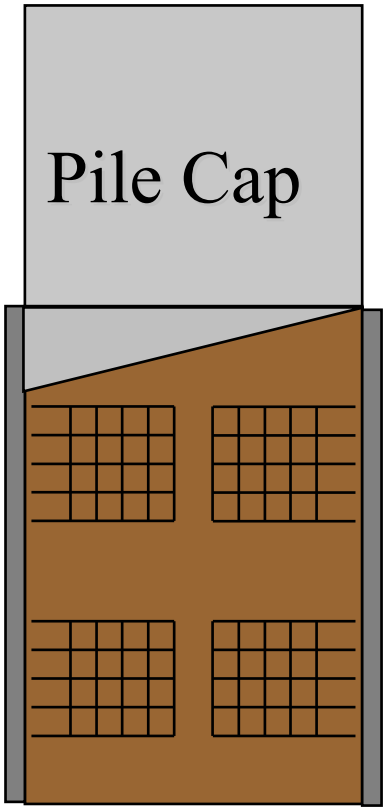




Future Tests



MSE walls with higher Pullout FS



MSE walls with skewed abutment face

Conclusions

- Deflection required to reach maximum passive state ranged from 3.0 - 5.0% of the pile cap height
- Log spiral theory agreed well with the ultimate passive resistance (P_u) results
- Force-displacement curve is hyperbolic
- Caltrans approach inconsistent in matching ultimate passive force and 50% low on average stiffness

Conclusions

- Narrow gravel zones can produce a major percentage of the passive resistance provided by full gravel backfill.
  - 3 ft wide zone provided 60%
  - 6 ft wide zone provided 80%
- MSE wingwalls may experience pullout. Need method to predict increased wall pressure.