DeepEX
Shoring Design Software

DEEP EXCAVATION
GEOTECHNICAL SOFTWARE & SOLUTIONS

Design of Deep Excavations

DeepEX Software Application

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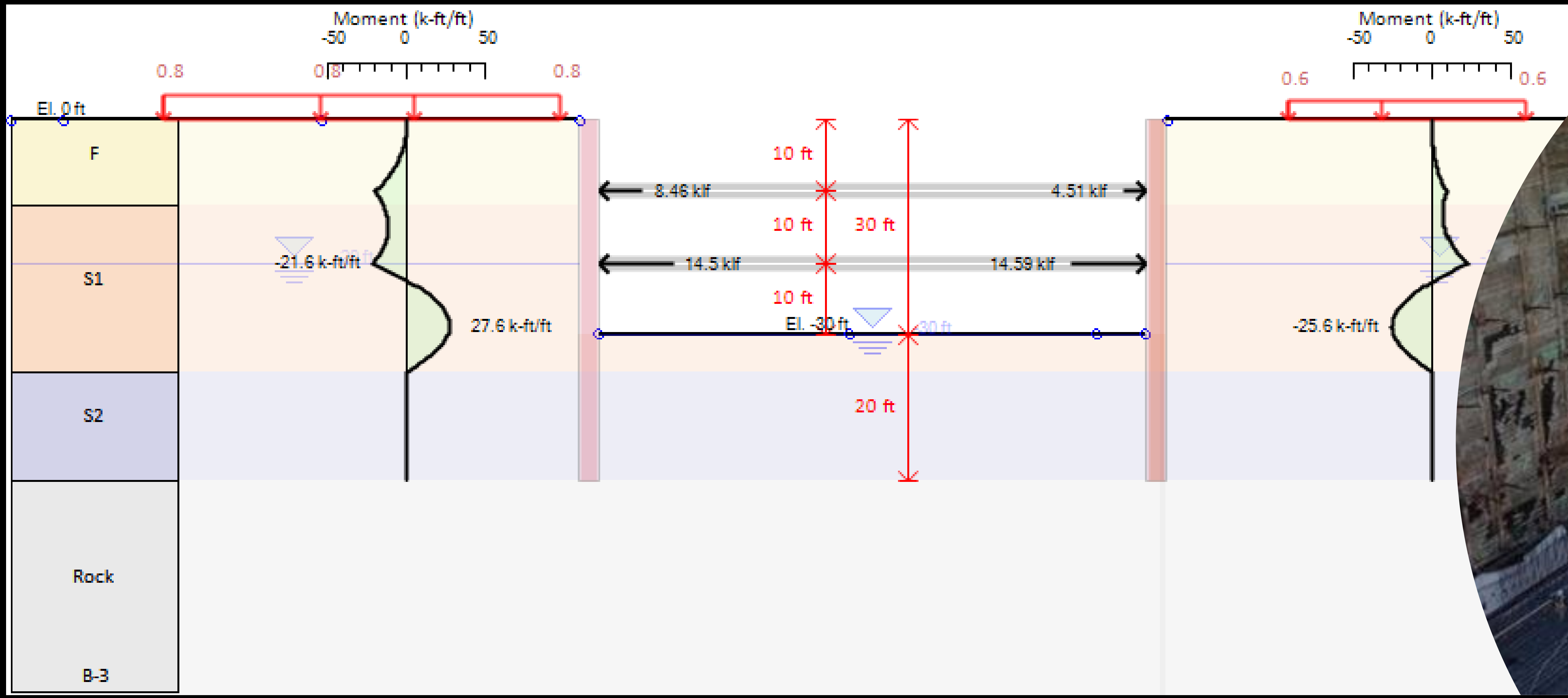

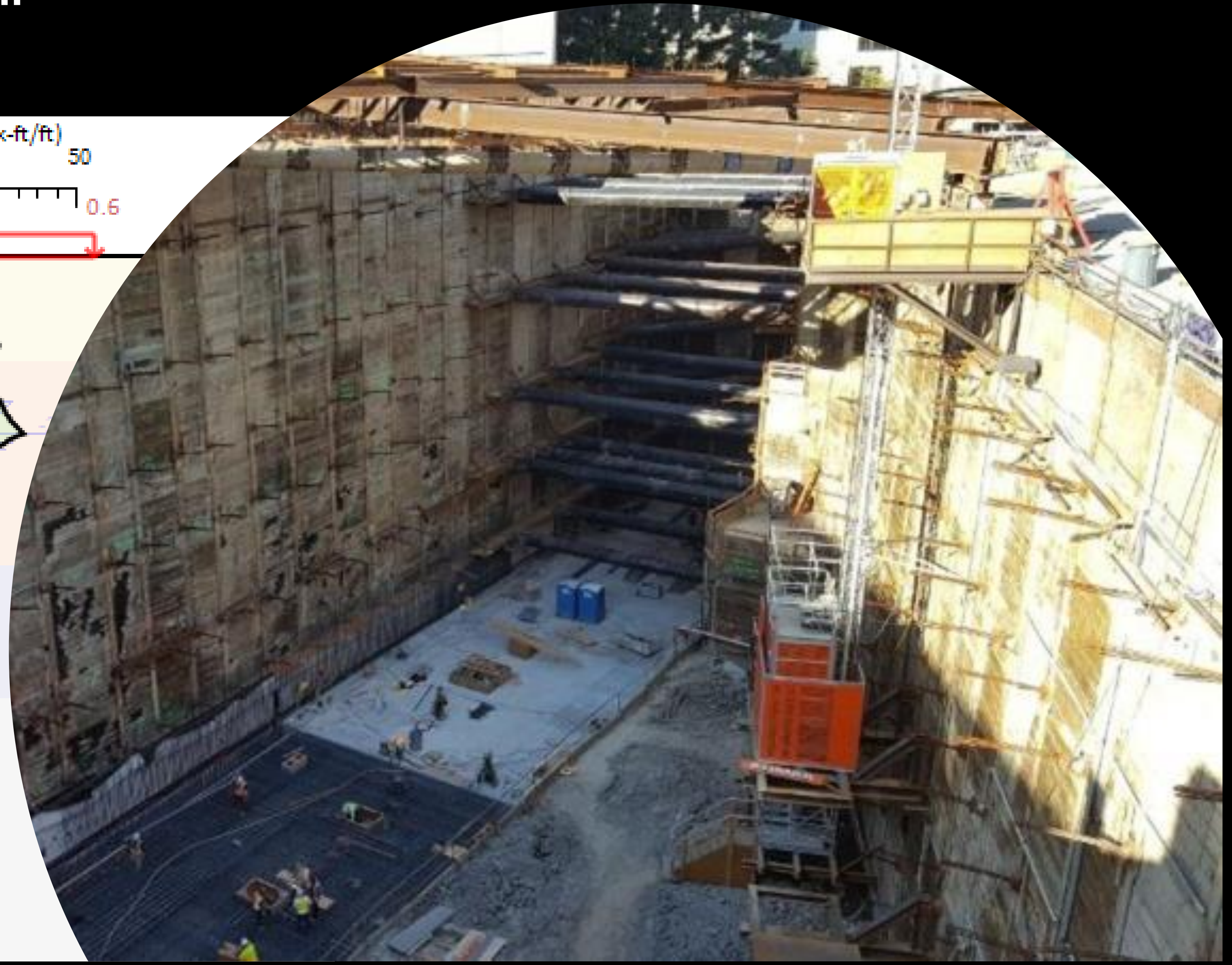

Introduction

Part 1: DeepEX: Theory and Implemented Methods - Limit Equilibrium, Non-Linear Analysis

Part 2: Use of DeepEX - Wall Types, Support Systems, Software Interface, Soil Properties & Stratigraphy

Part 3: DeepEX - Design Examples & Training
- ✓ Anchored Walls - Excavations with Tiebacks
- ✓ Braced Excavations & Cofferdams
- ✓ Top-Down Excavations (Slabs)
- ✓ Deadman Wall Systems
- ✓ Circular Shafts
- ✓ Box Excavations
- ✓ Stepped Excavations

Part 4: Deep Excavation Case Studies

Part 5: DeepEX Additional Modules

DeepEX
Shoring Design Software

Our Company

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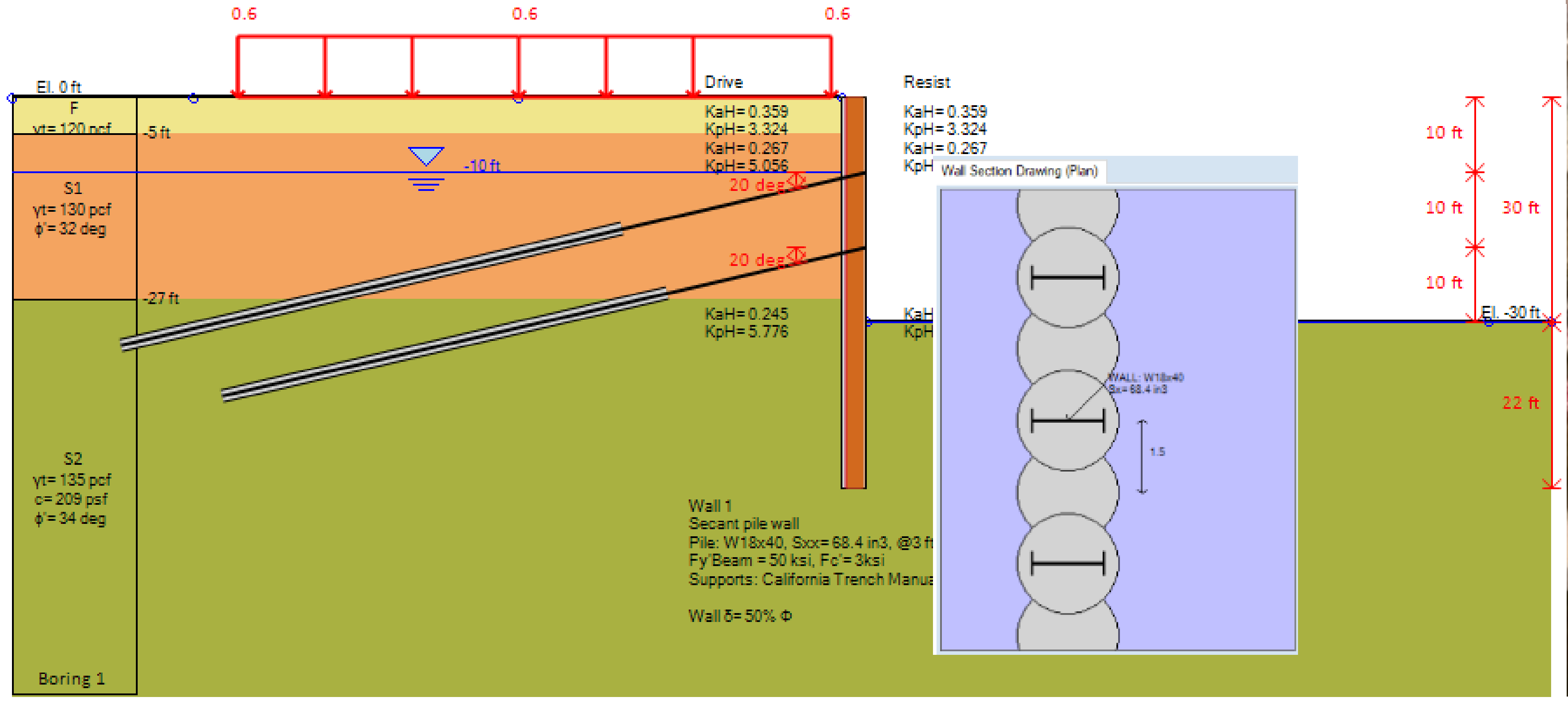
- ✓ Software solutions for excavation and foundation professionals
- ✓ Consulting Services - Design of deep excavations and pile foundations
- ✓ Virtual Reality applications for geotechnical engineers and contractors

DEEP EX · HOLODEEP EX · DEEP FND · HELIX PILE · SNAIL PLUS · QUAY WALLS · SITE MASTER

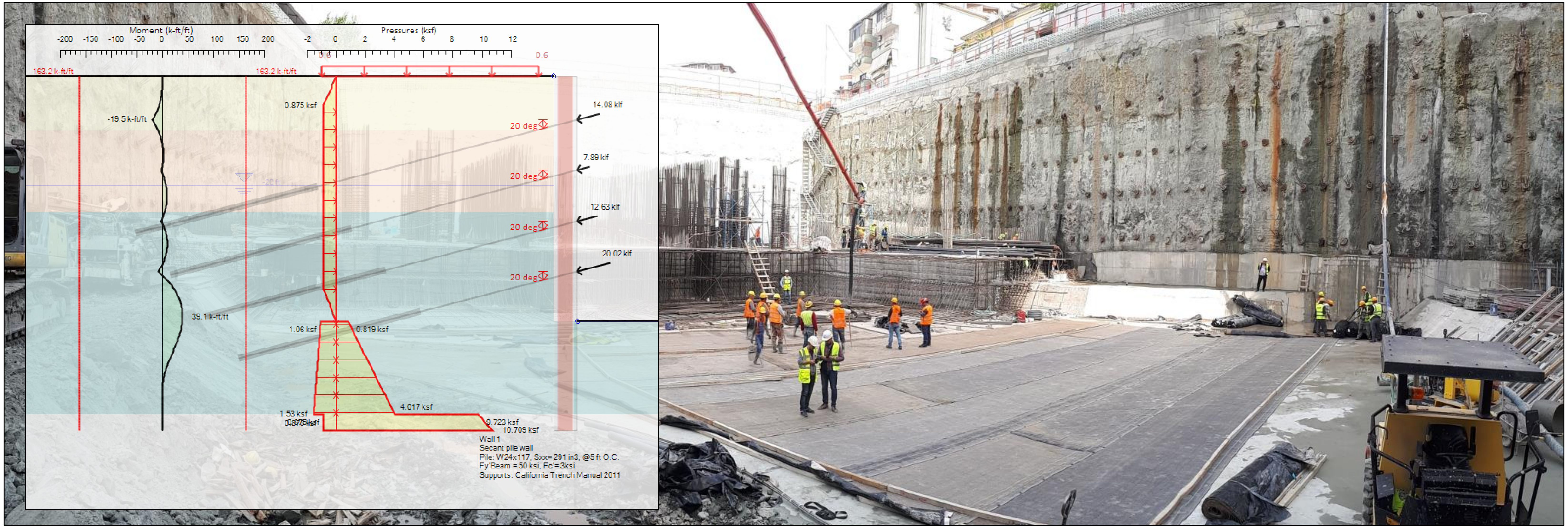
TRENCH · PILE D/R · DEVIATE VR · GeoBase.io · RCsolver · SteelBeam · WickDrains

Deep Excavation: Typically deeper than 3.5m, that requires structural support.

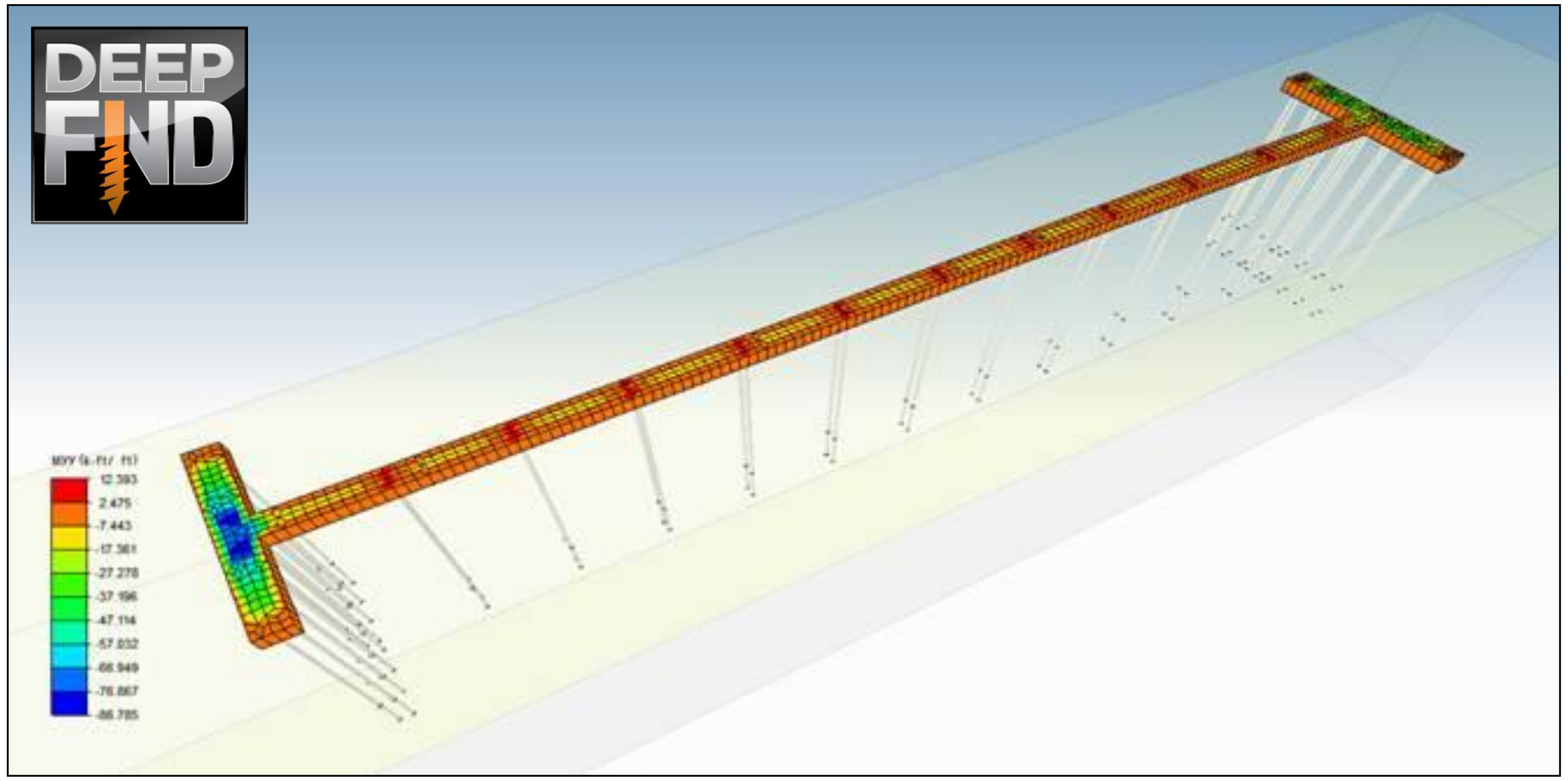
- A deep excavation system has to retain earth, water, and neighboring structures
- Unknown factors and risks
- Soil properties estimation
- Protect adjacent properties
- Design issues and Code issues
- Economy
- Constructability



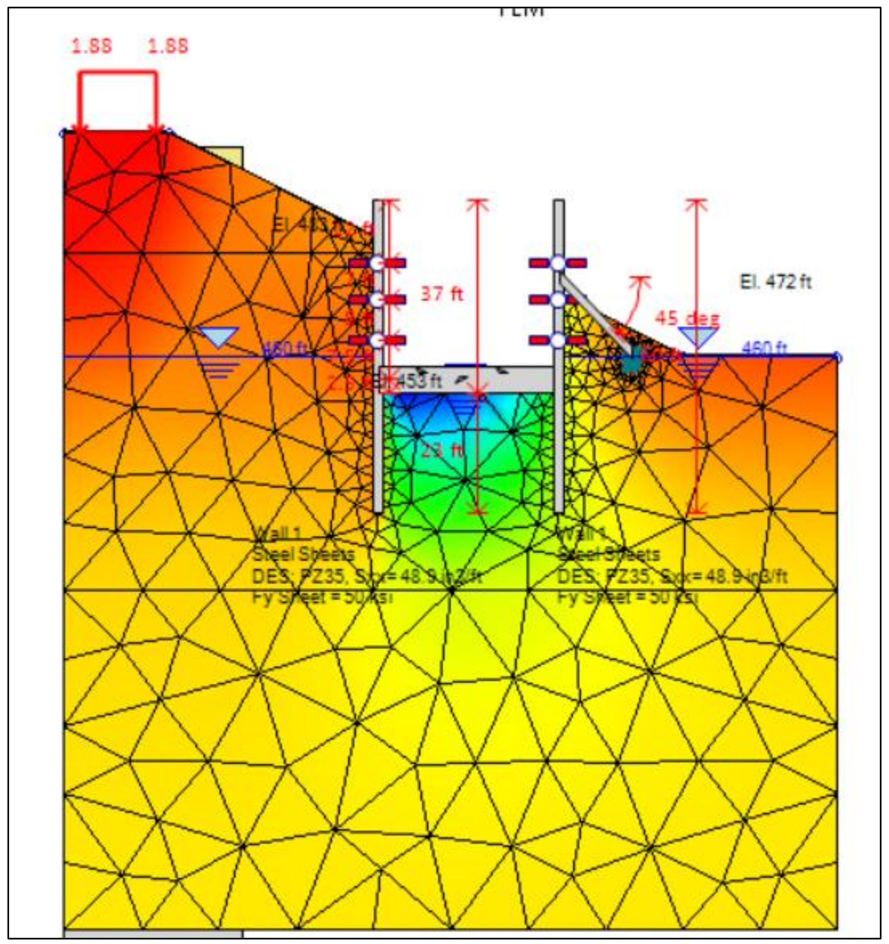
DeepEX: Theoretical Background & Methods

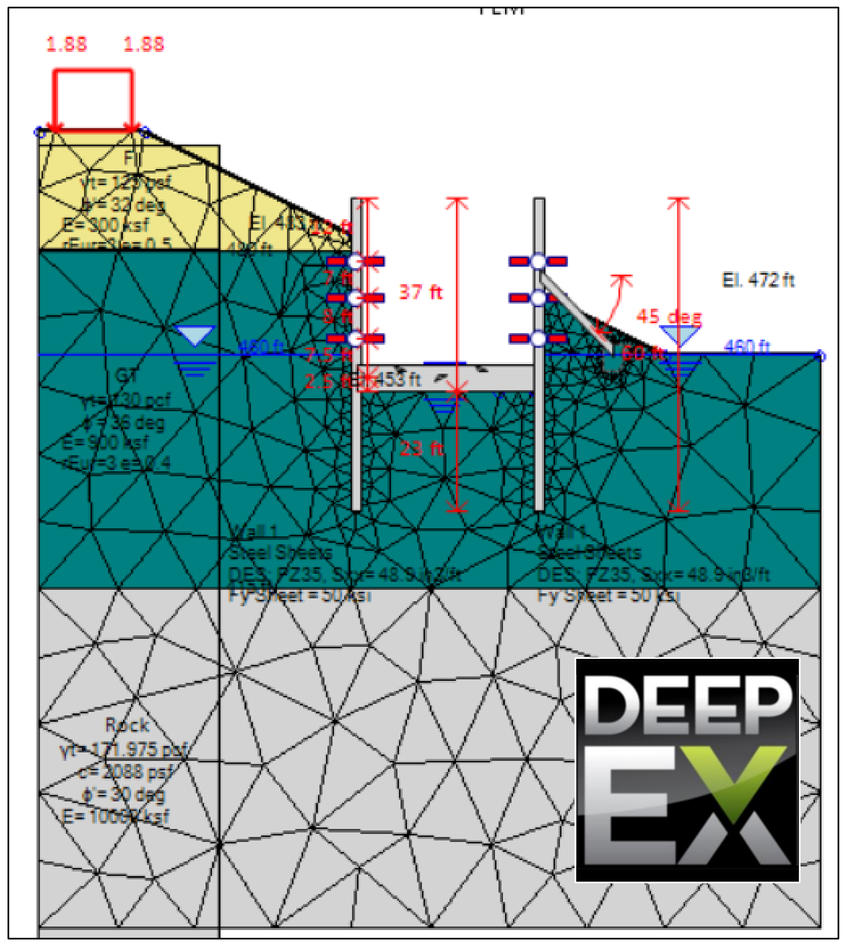


Access deepexcavation.com
Theory and Methods



Numerical simulations are part of everyday design tasks.





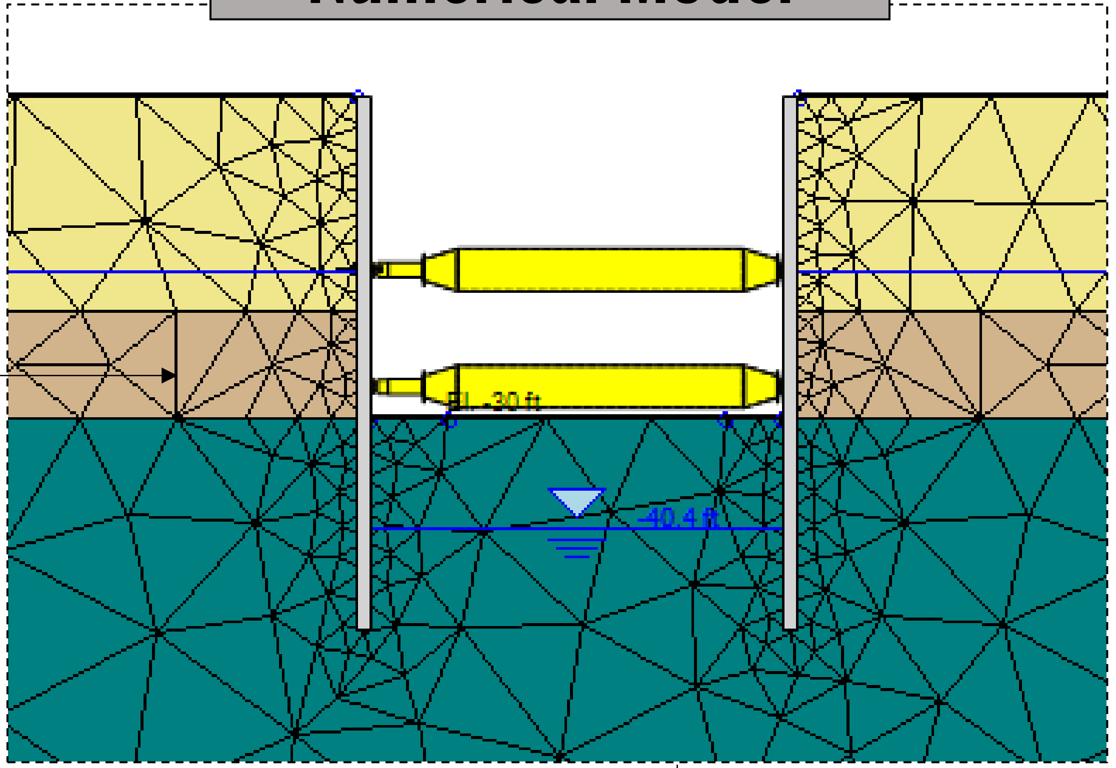
Necessary condition:
Model Accuracy!!!

Quantitative and qualitative accuracy!!

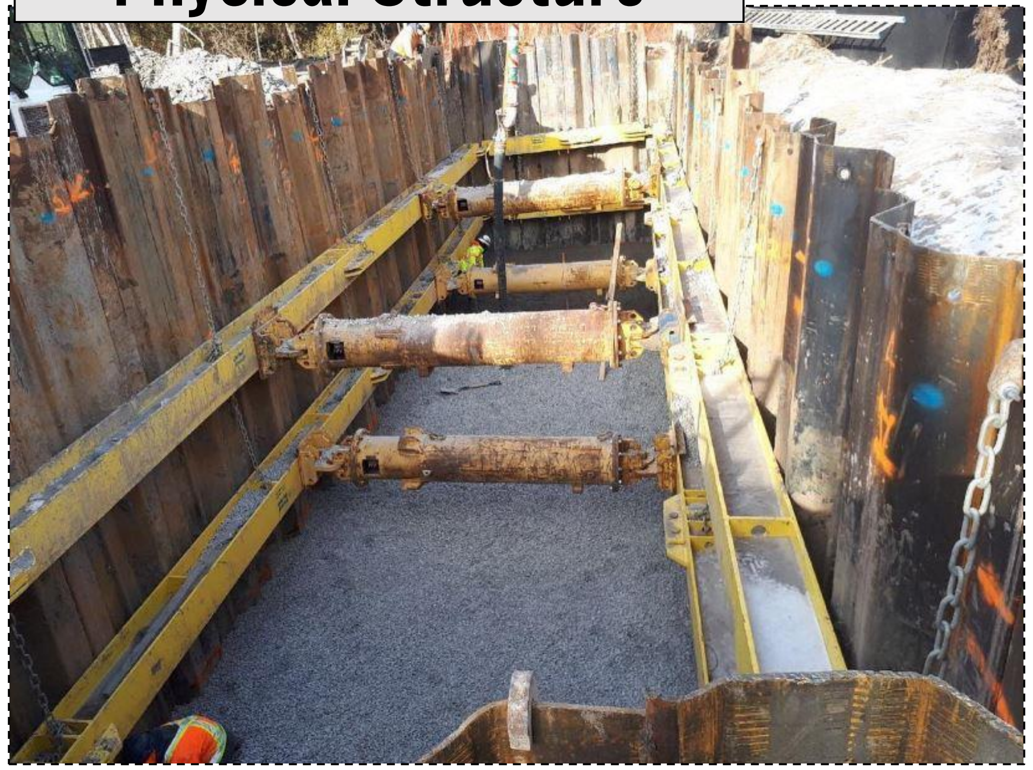
in site monitoring

Model Input (Soil stratigraphy, material properties etc)

Numerical Model



Physical Structure



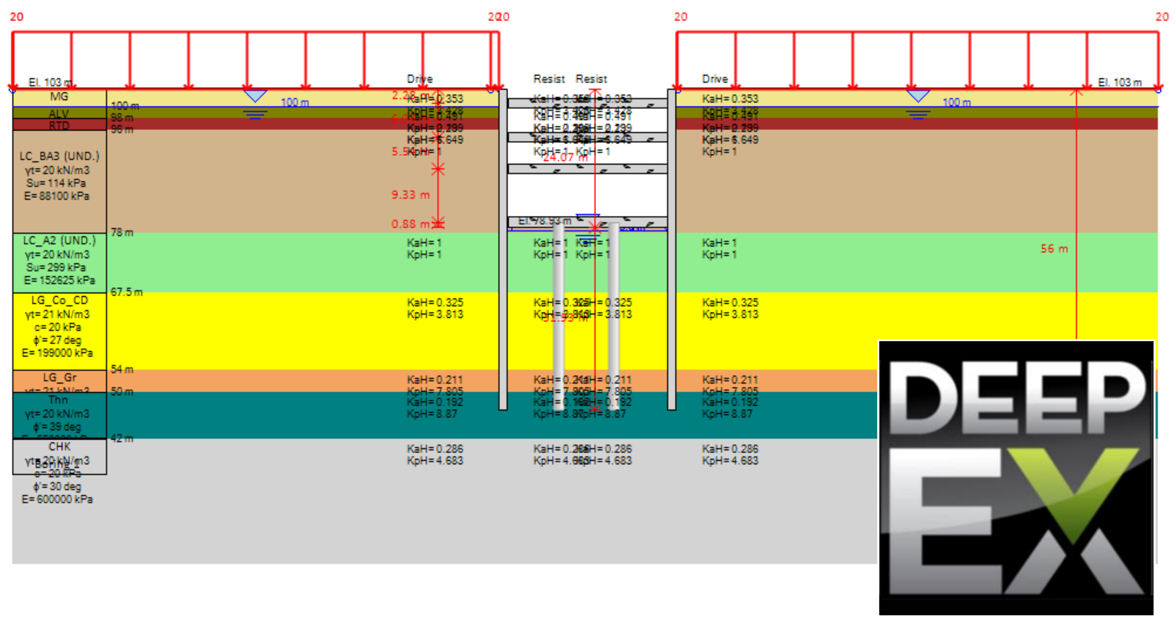
User Modelling decisions (Analysis method, constitutive models etc)

Forecasting response

Different Constitutive material models

Different analysis Methods:
LEM,NL,FEM

DeepEX

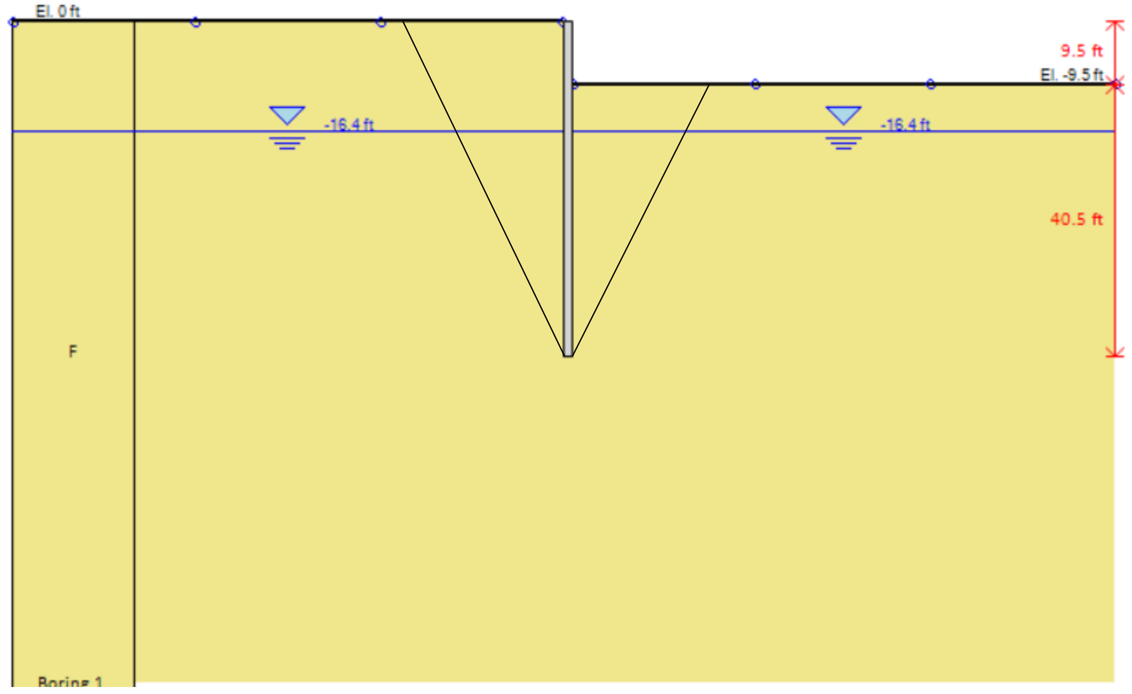


Different support models

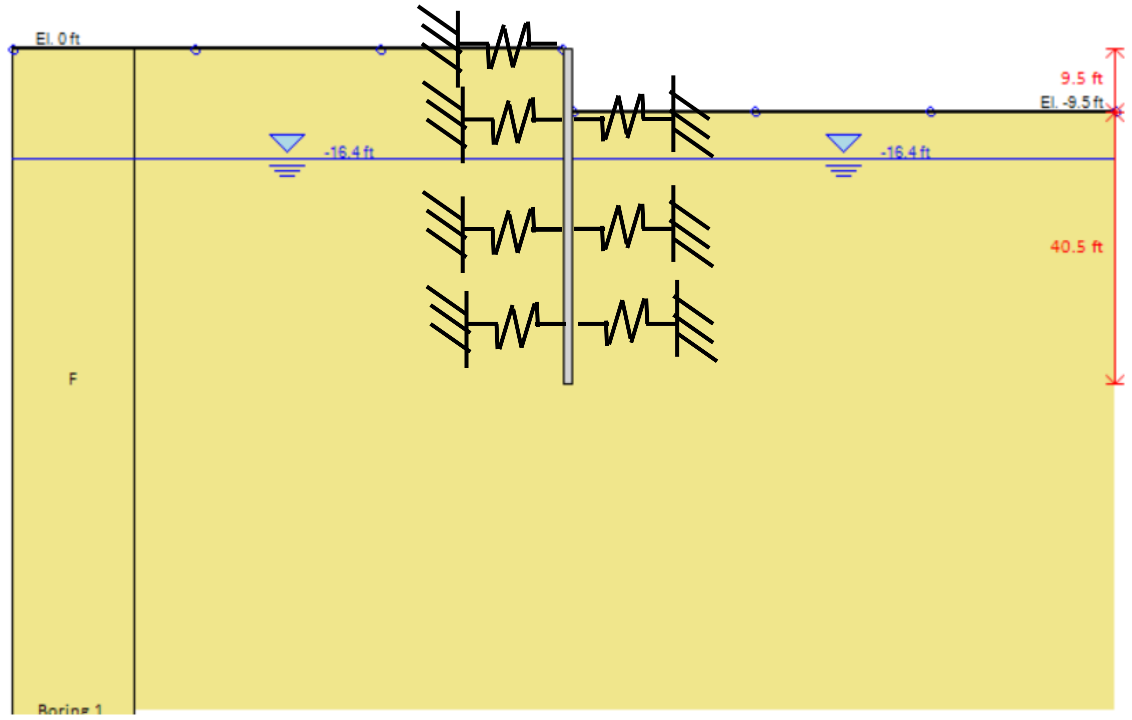
Different soil pressure methods

It is important to have a good understanding of the analysis method derivation and limitations

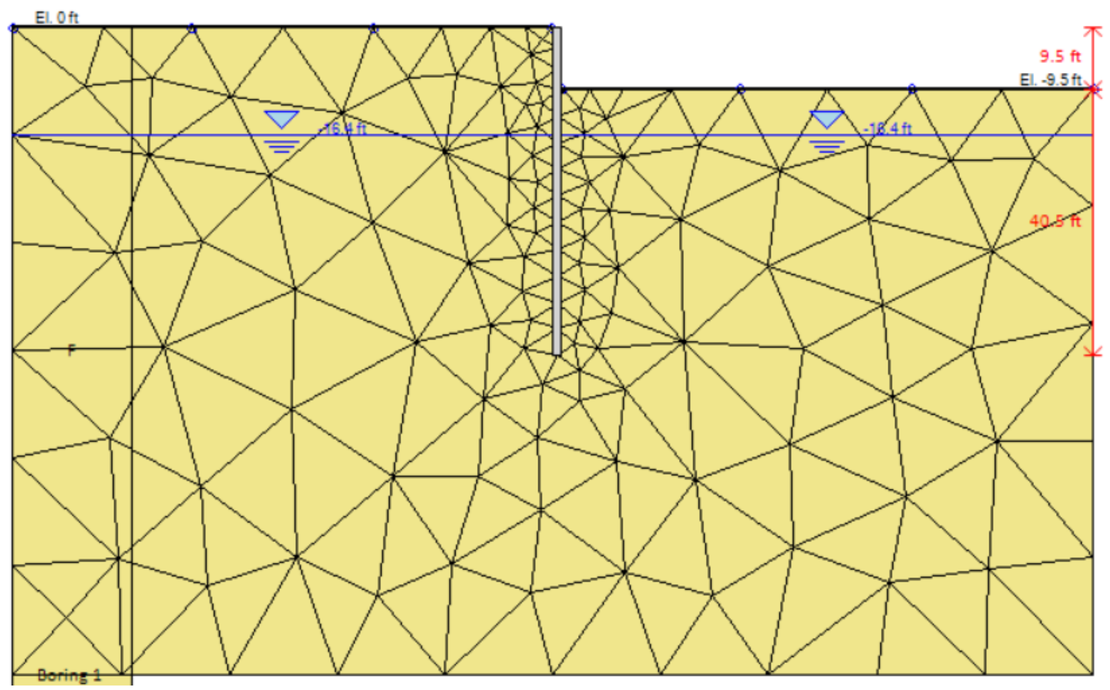
METHODS available in the software:



Limit equilibrium Method



Elastoplastic Winkler spring Method

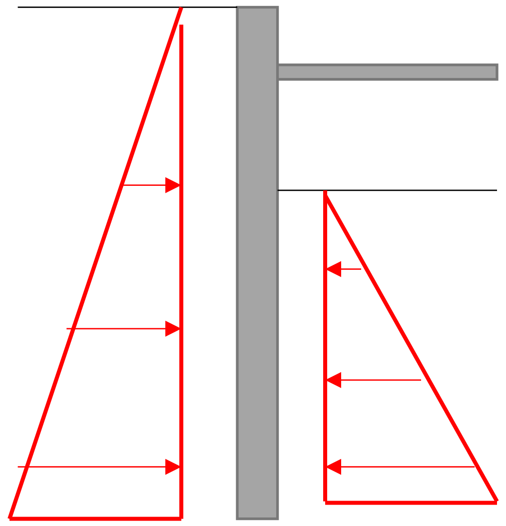


Finite element Method

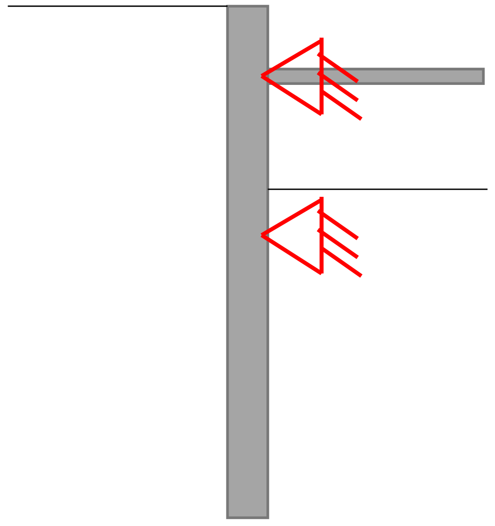
Limit Equilibrium Analysis Concept (LEM)

Limit Equilibrium Method (LEM) :

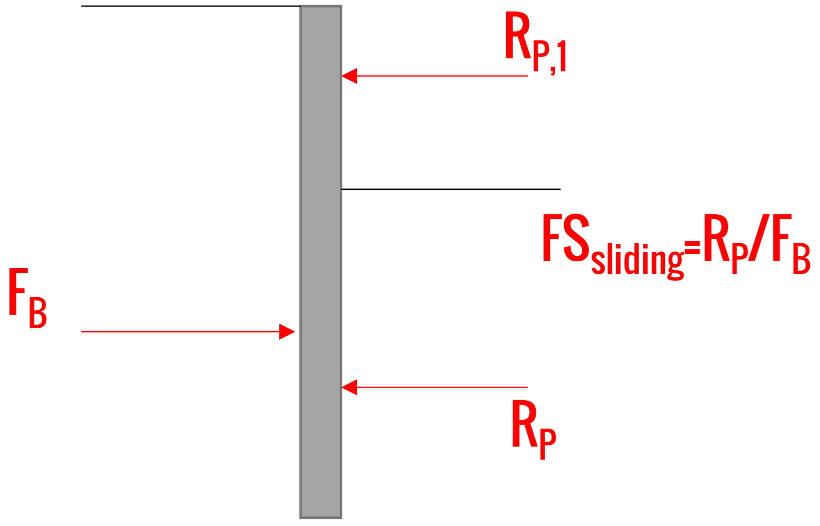
- Easy method to verify. Gives a back check for more rigorous methods.
- pre-failure strain is ignored
- Soil-structure interaction ignored



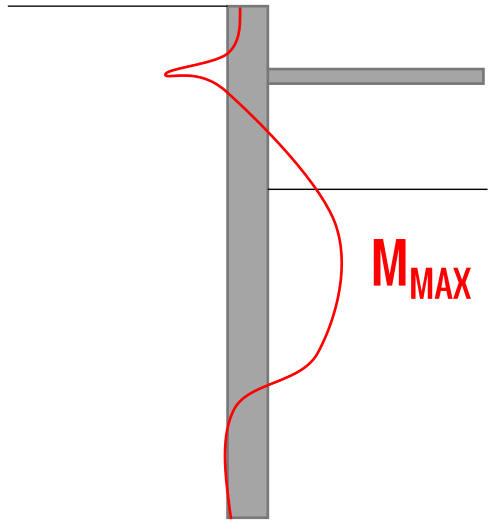
Calculation of lateral earth pressures.



Determine fixity locations and run beam analysis.



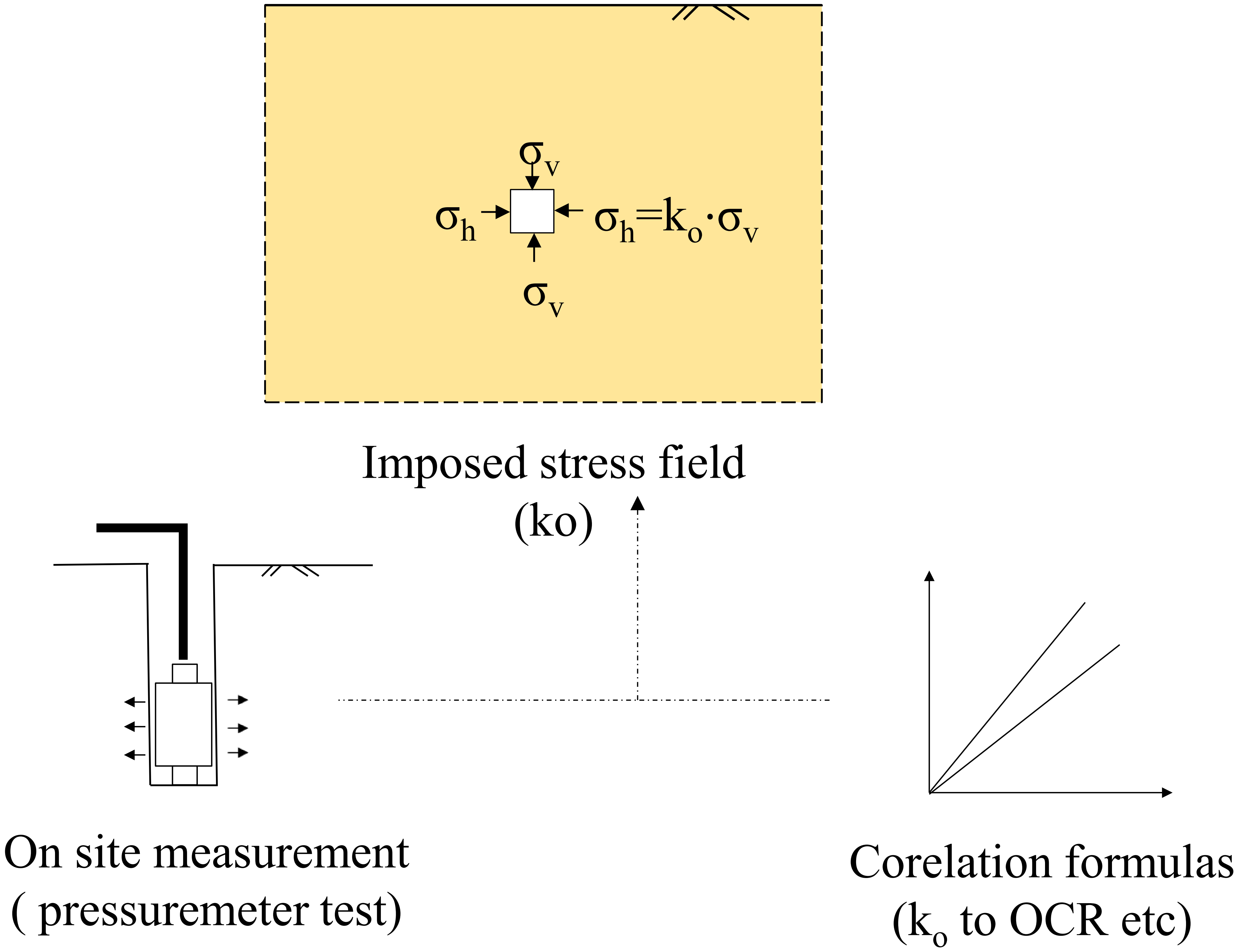
Calculate stability checks on the wall



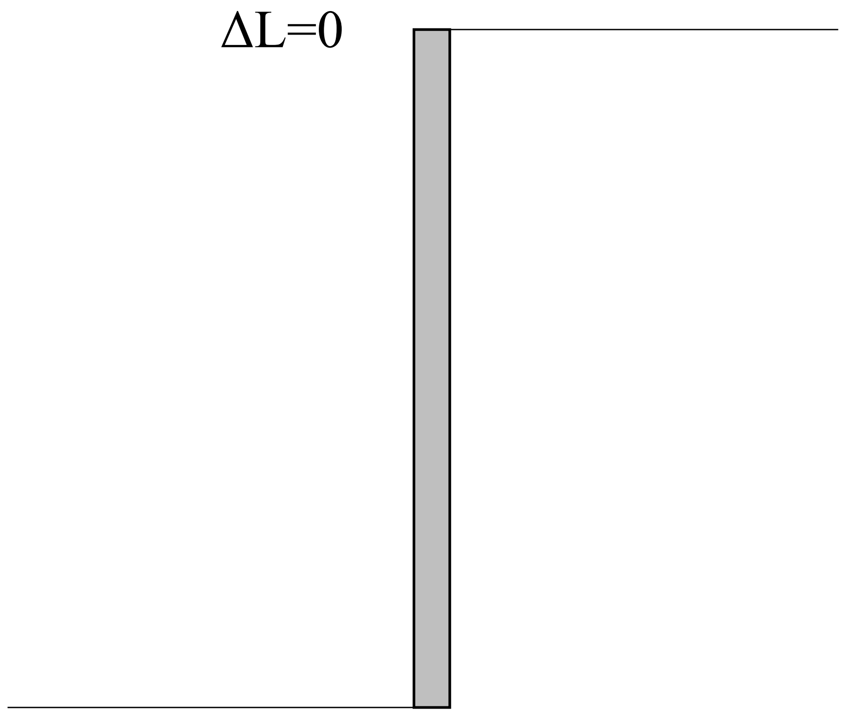
Calculate structural design checks

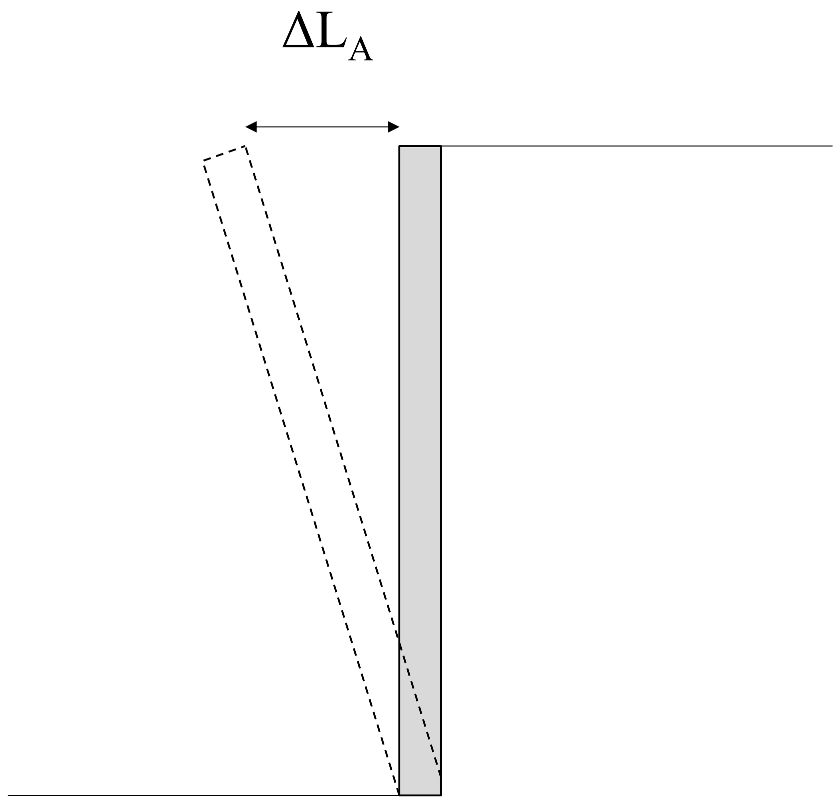
Earth Coefficients in DeepEX

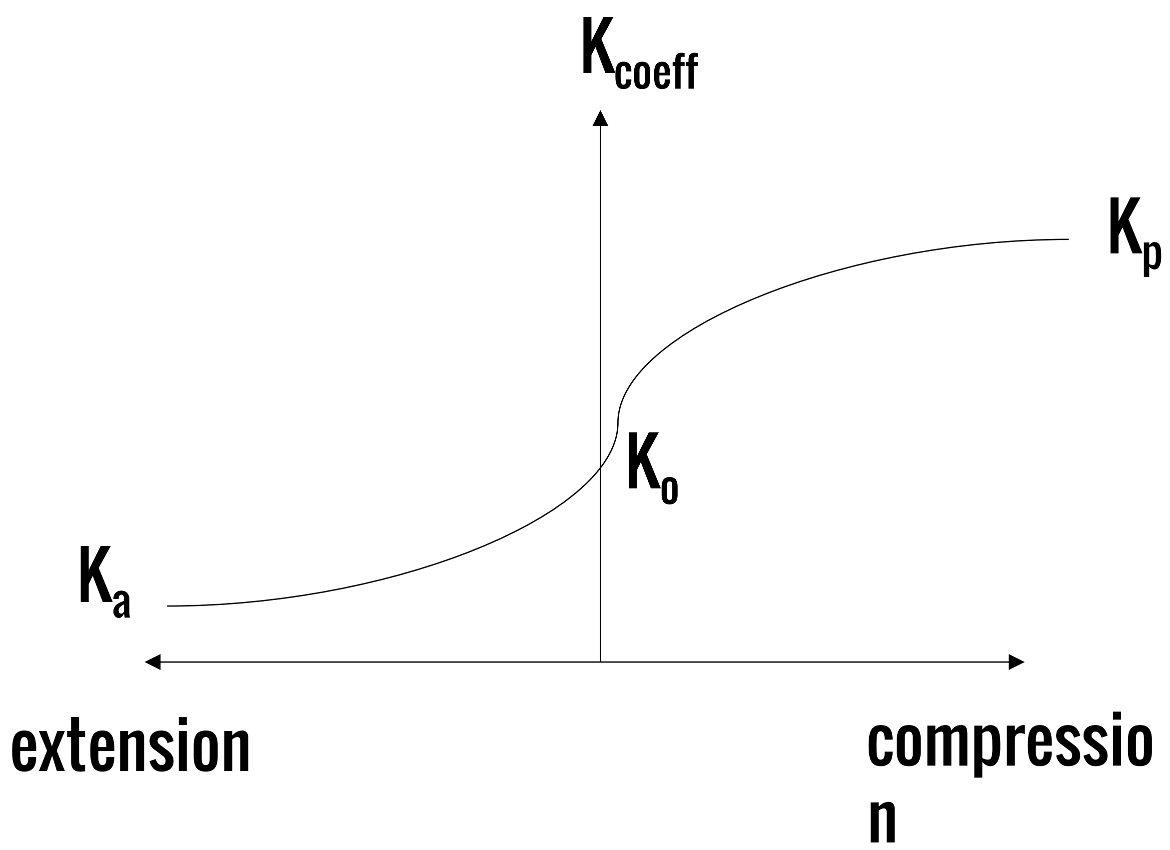
At rest conditions (field stress conditions prior to the excavation):

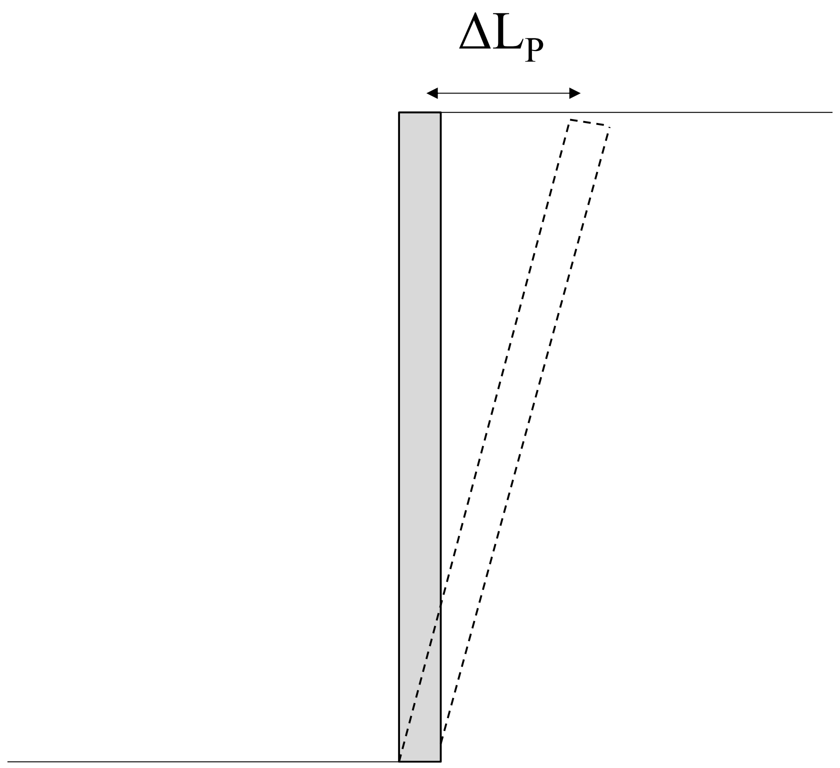


Earth Coefficients in DeepEX





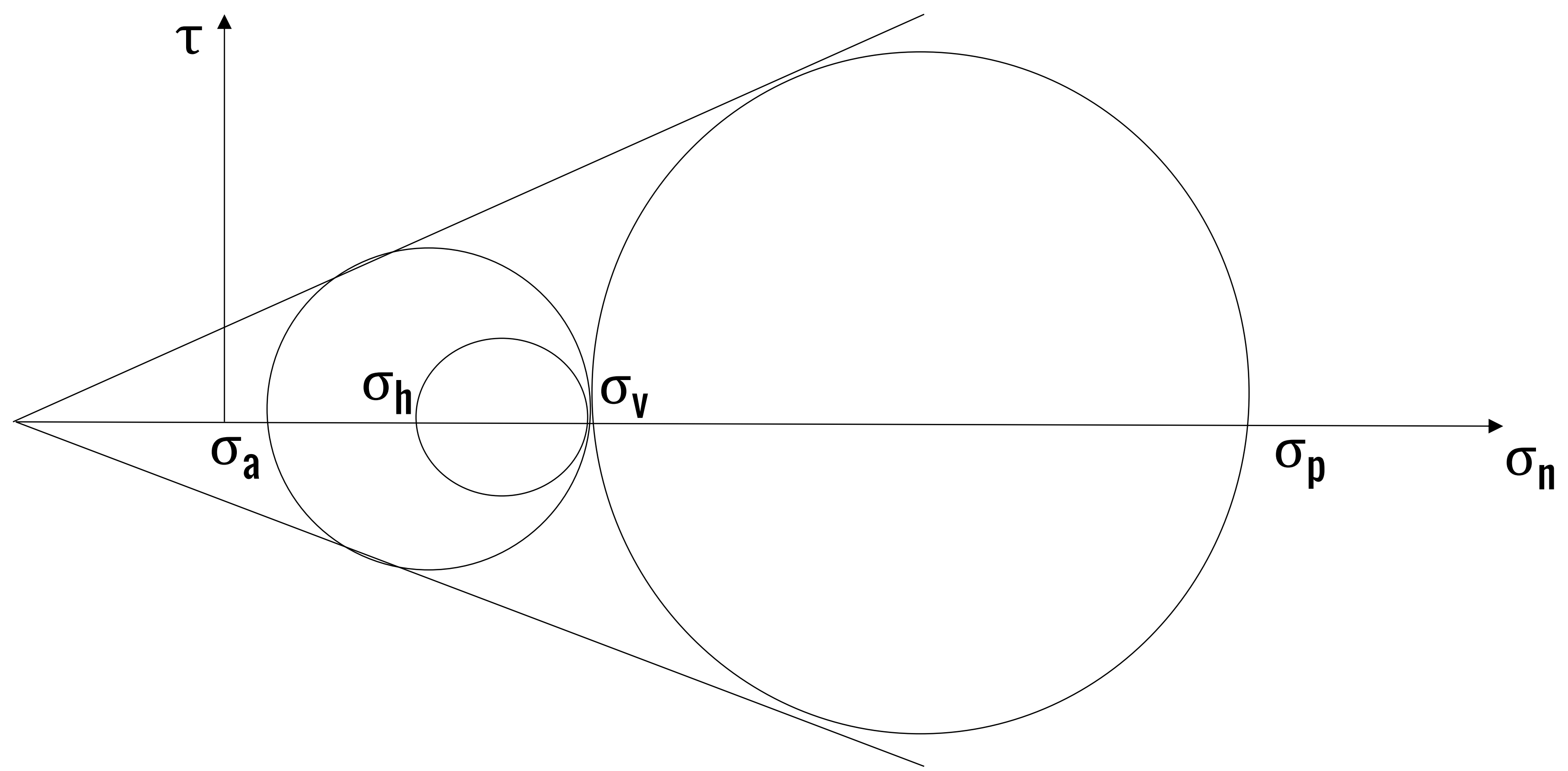


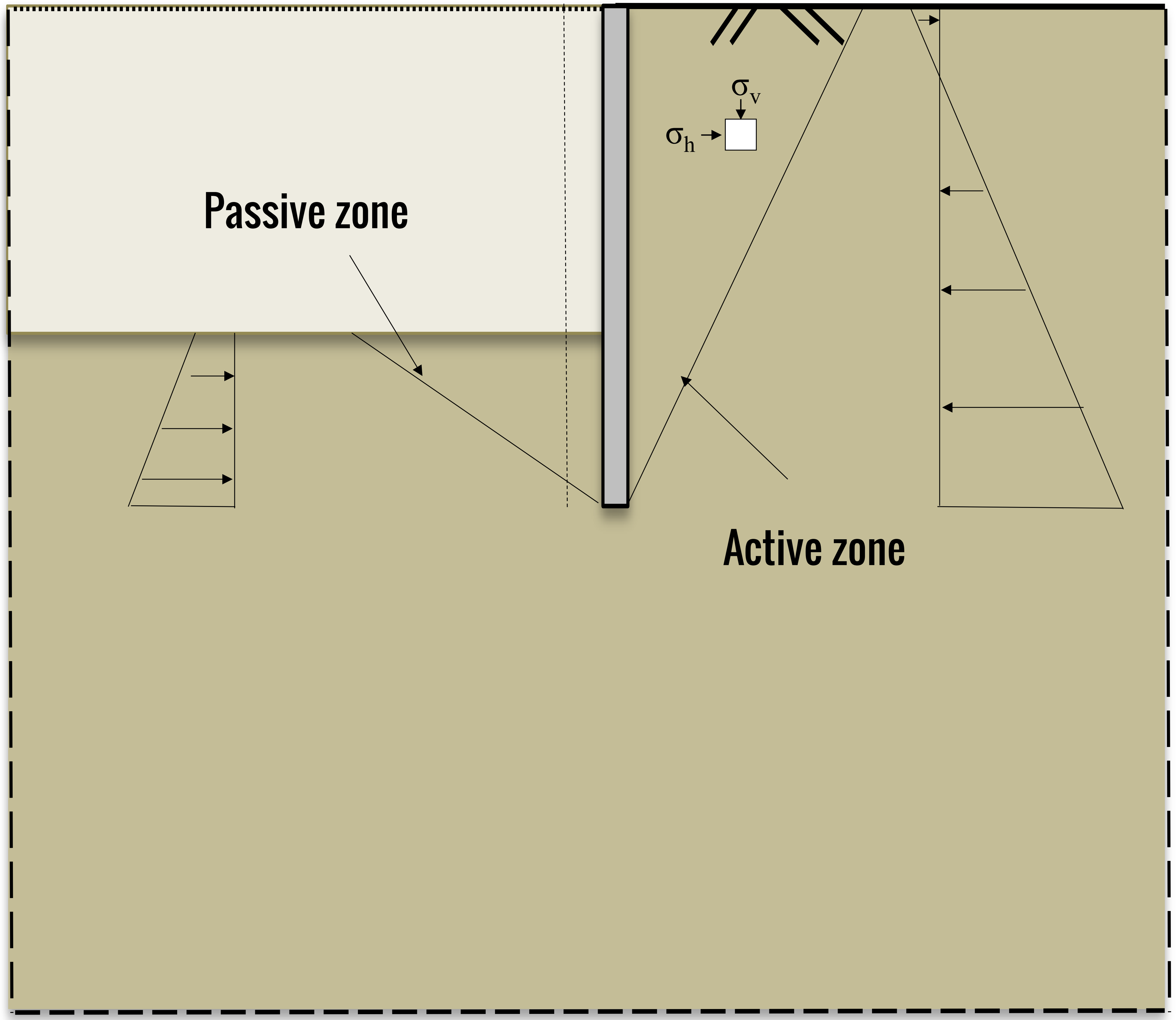


Earth Coefficients in DeepEX

Rankine earth pressure theory (1857):

- Based on plastic equilibrium concept
- No friction between wall and soil

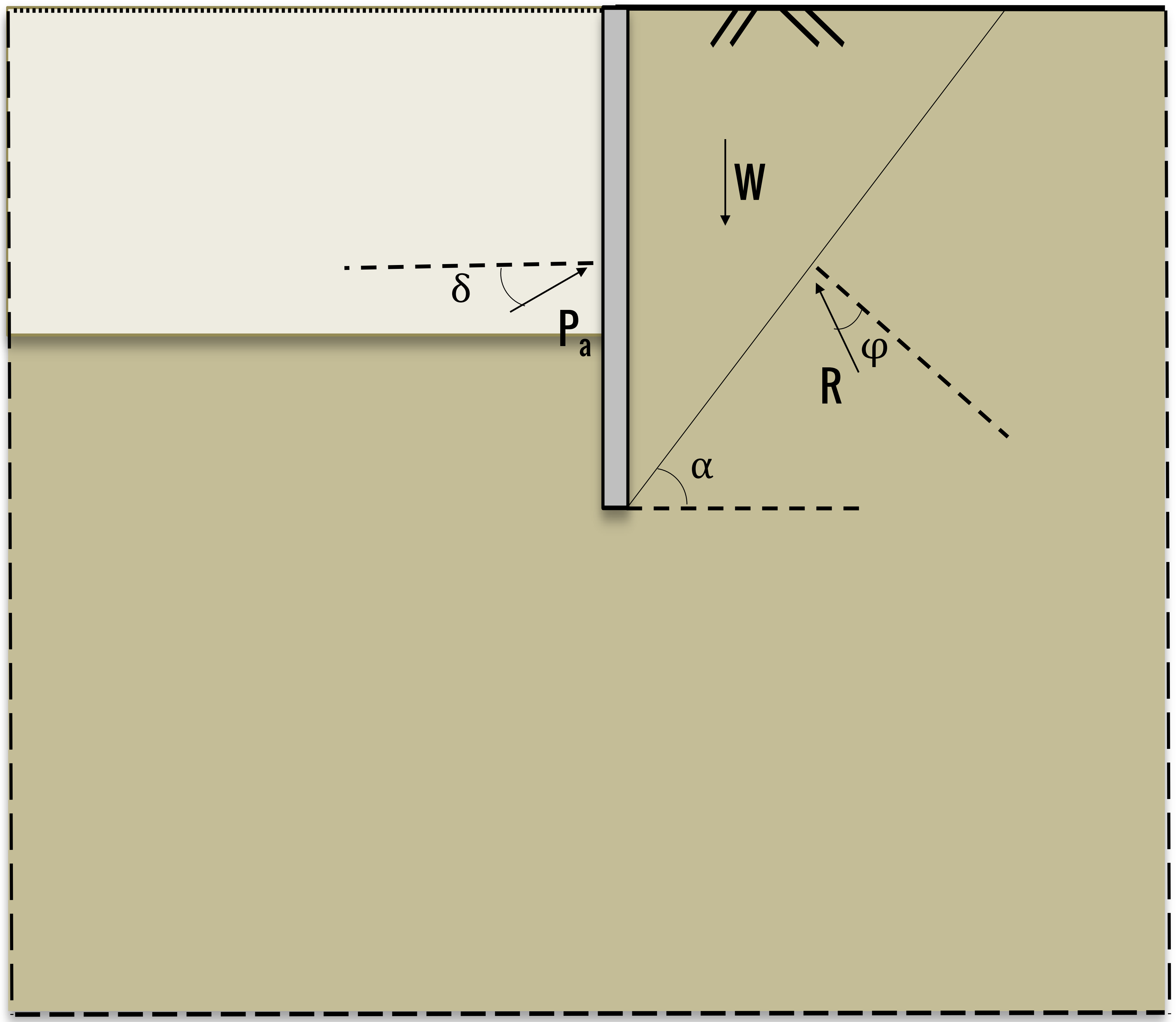




Earth Coefficients in DeepEX

Coulomb earth pressure theory (1776):

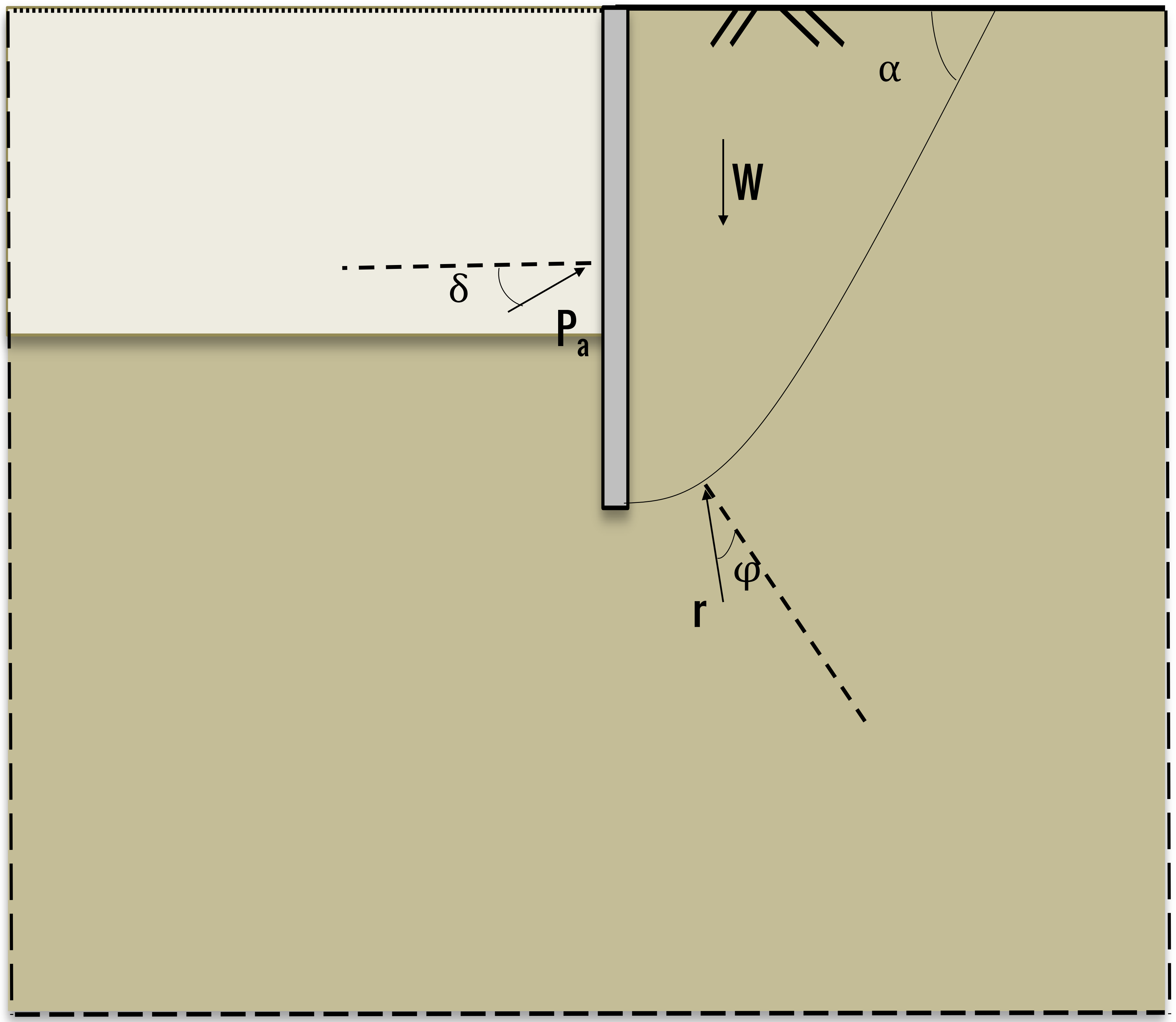
- Failure surface is a plane
- friction between wall and soil can be considered
- Arbitrary slope at the sides of the wall



Earth Coefficients in DeepEX

Caquot and Kerisel earth pressure theory (1948):

- Failure surface is an elliptical curved plane
- Eurocode 7 and NAVFAC charts based on the theory

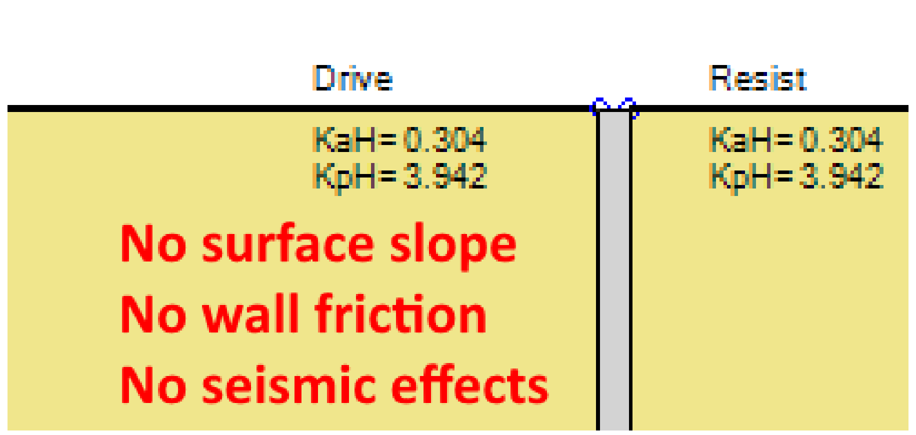


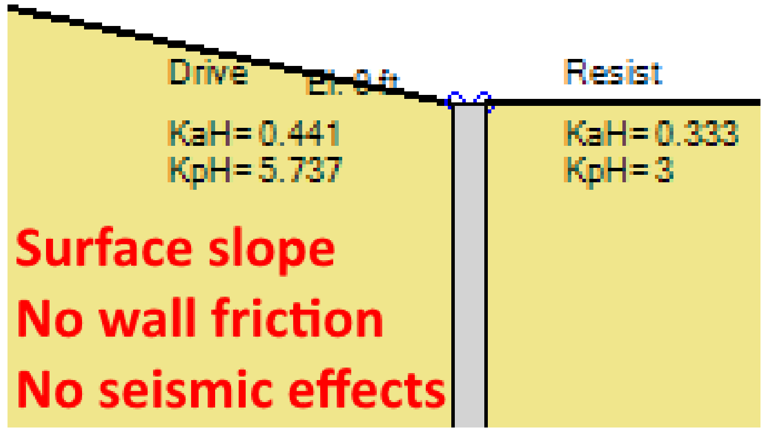
Earth Coefficients in DeepEX

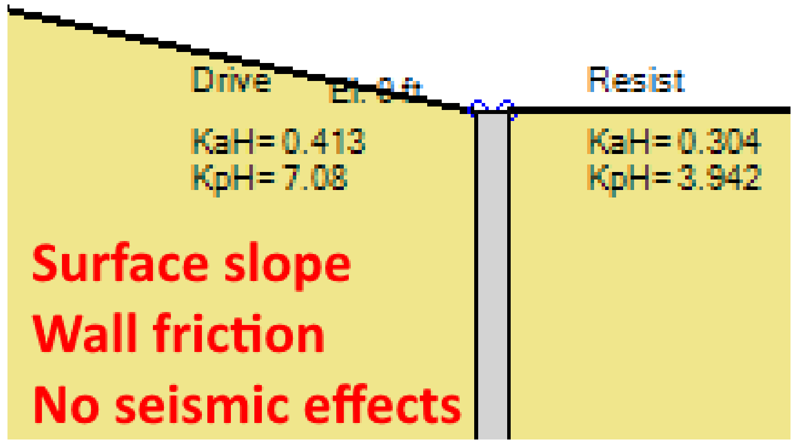
DeepEX Automatic Method Selection According to Project Parameters

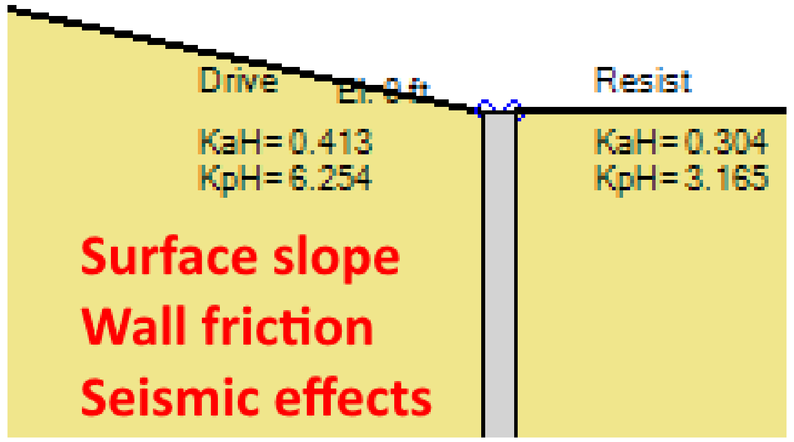
Active Coefficient Ka				
Parameters	Horizontal Surface	Inclined Surface	Wall Friction Considered	Seismic Effects Applied
Method	**Rankine**	**Coulomb**	**Coulomb**	**No Effect**

Passive Coefficient Kp				
Parameters	Horizontal Surface	Inclined Surface	Wall Friction Considered	Seismic Effects Applied
Method	**Rankine**	**Coulomb**	**Caquot-Kerisel**	**Lancelotta**



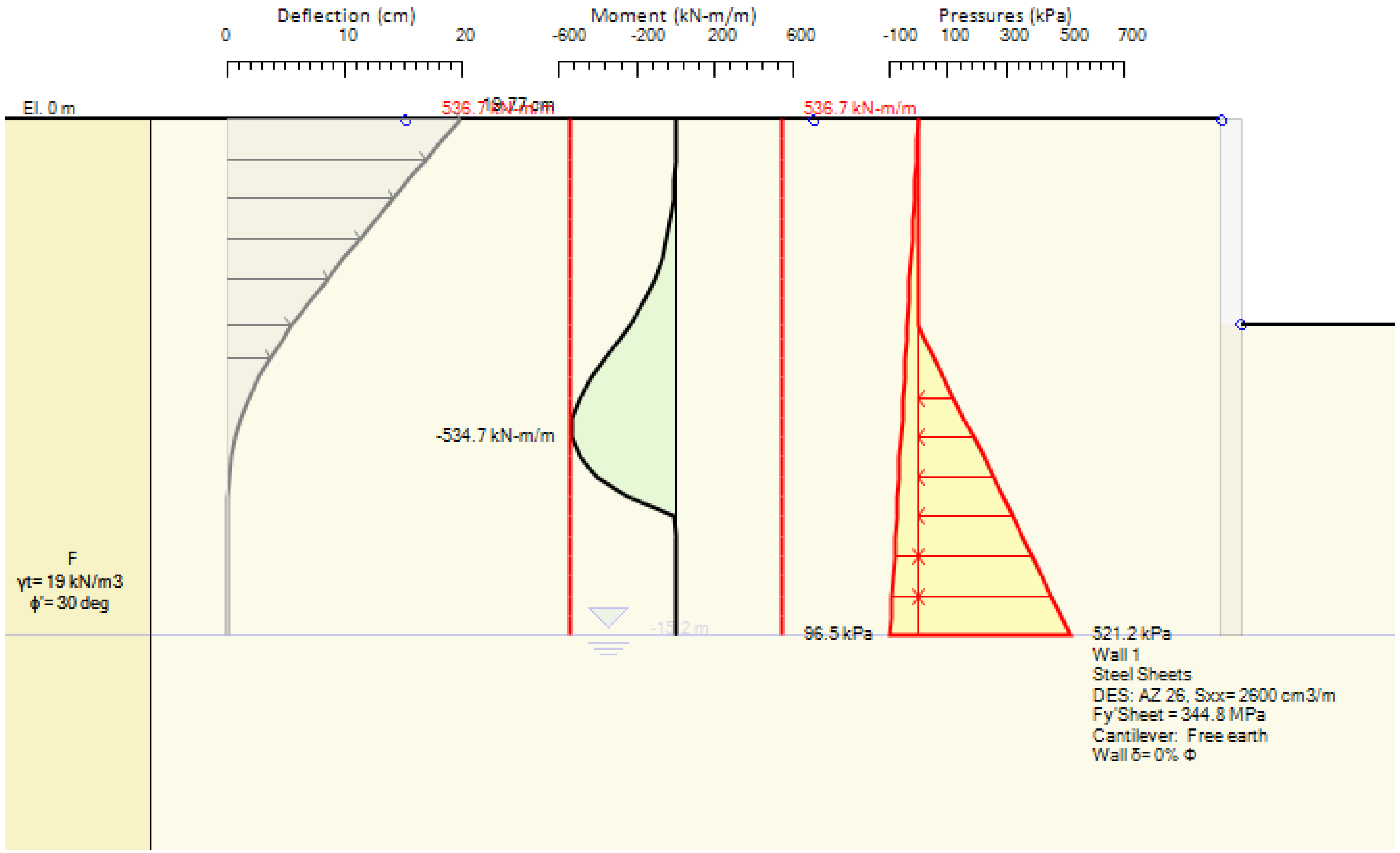




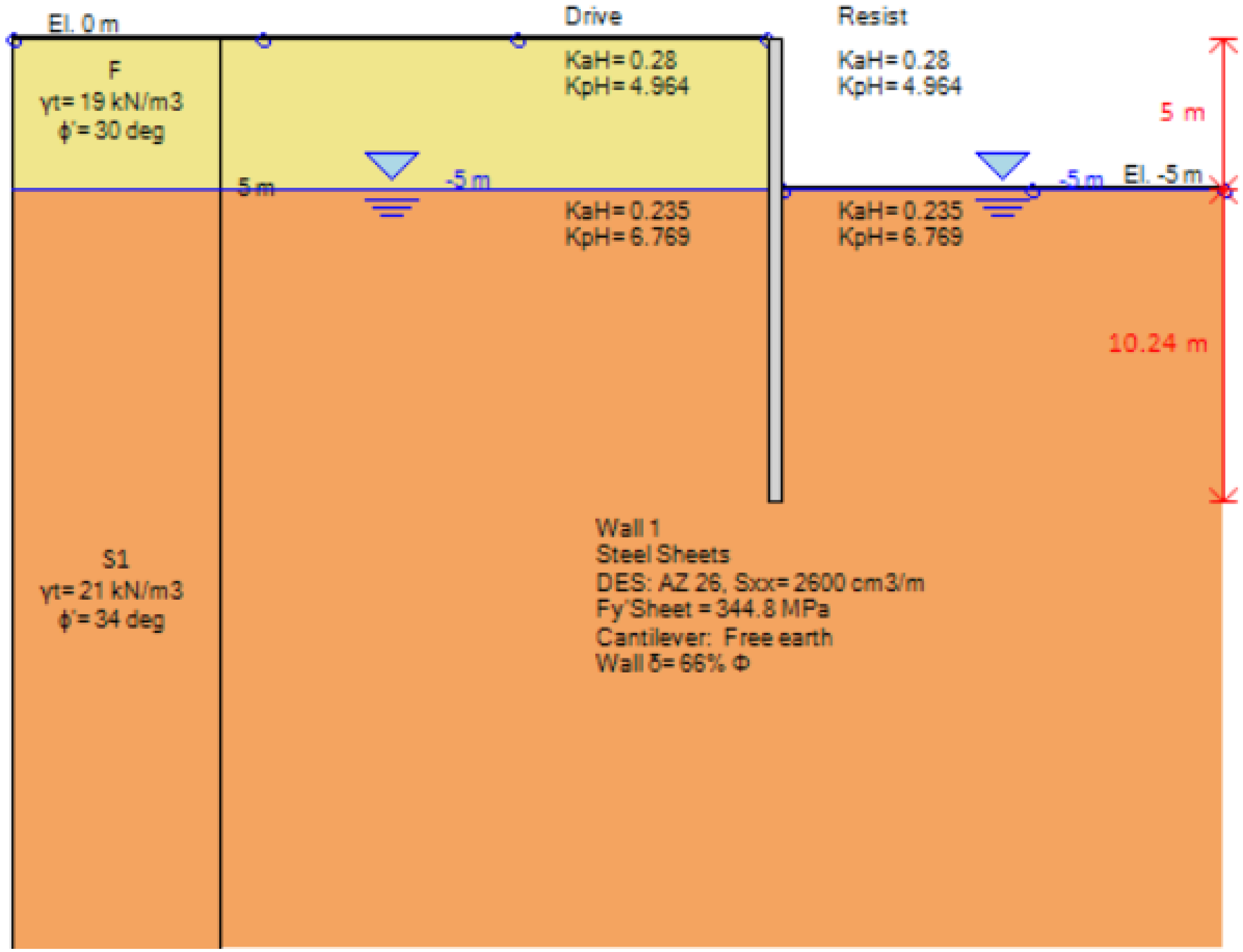


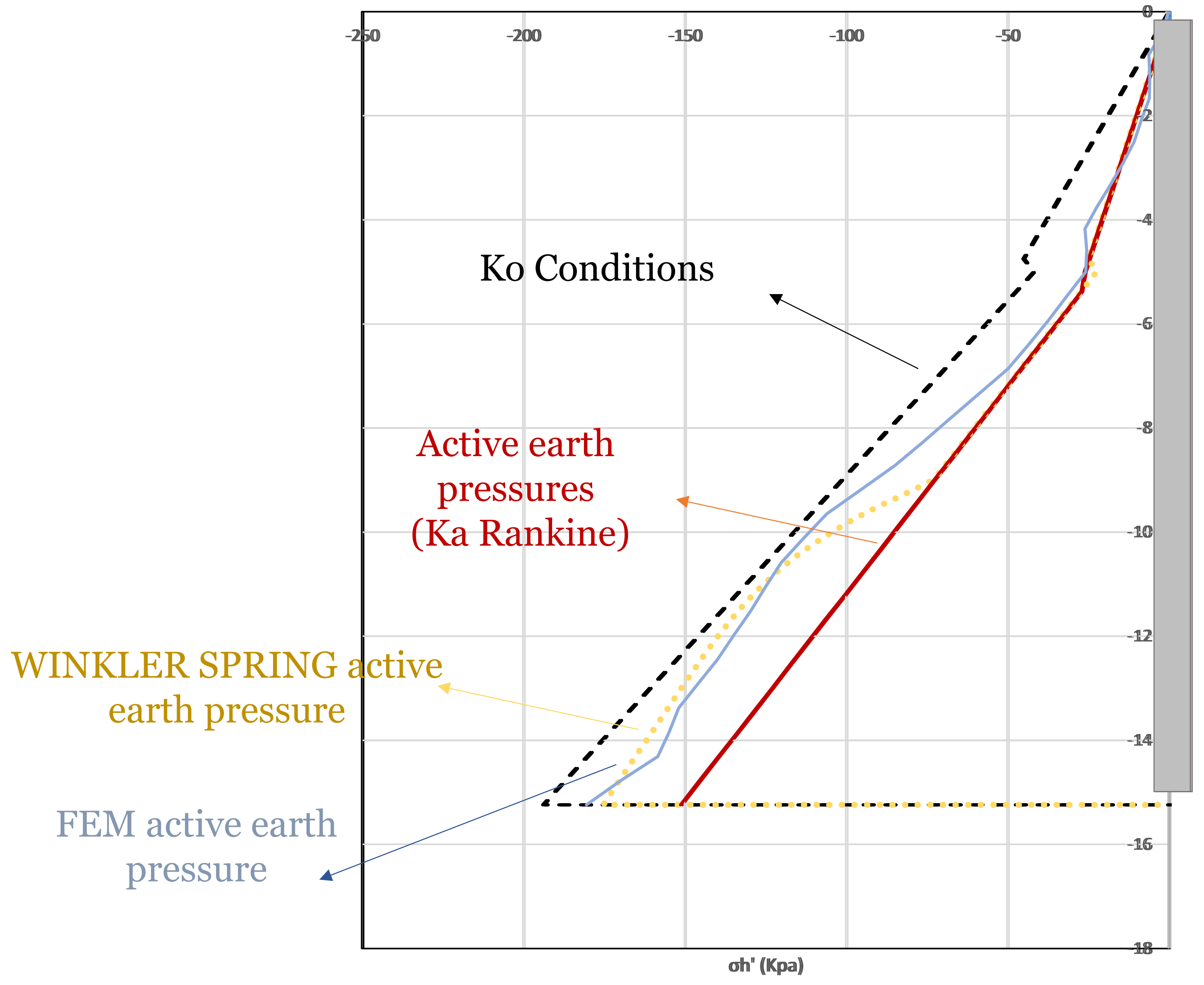
LIMITATIONS of theoretical method

Example 1:



Earth Coefficients in DeepEX





Active pressure

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Earth Coefficients in DeepEX

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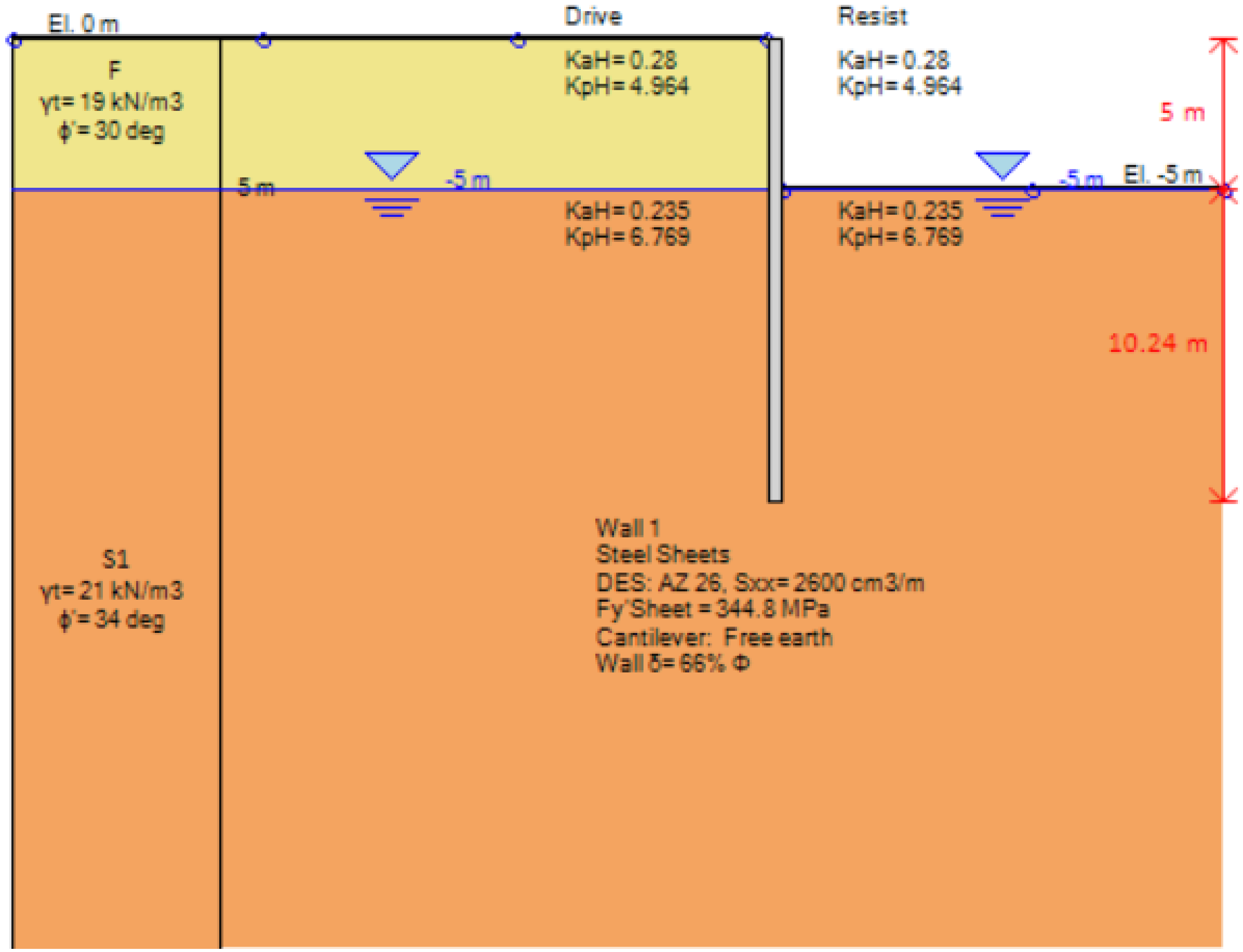
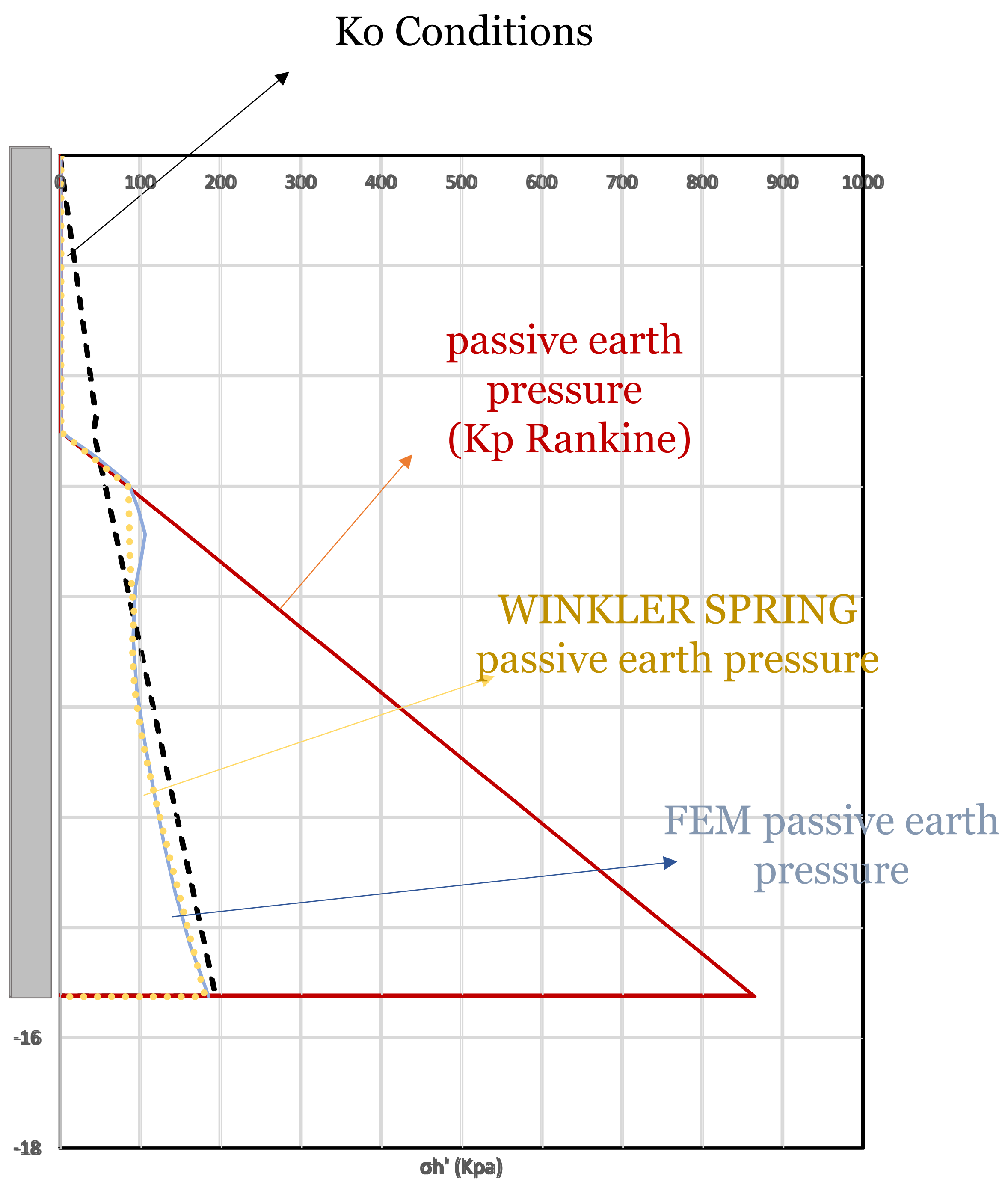
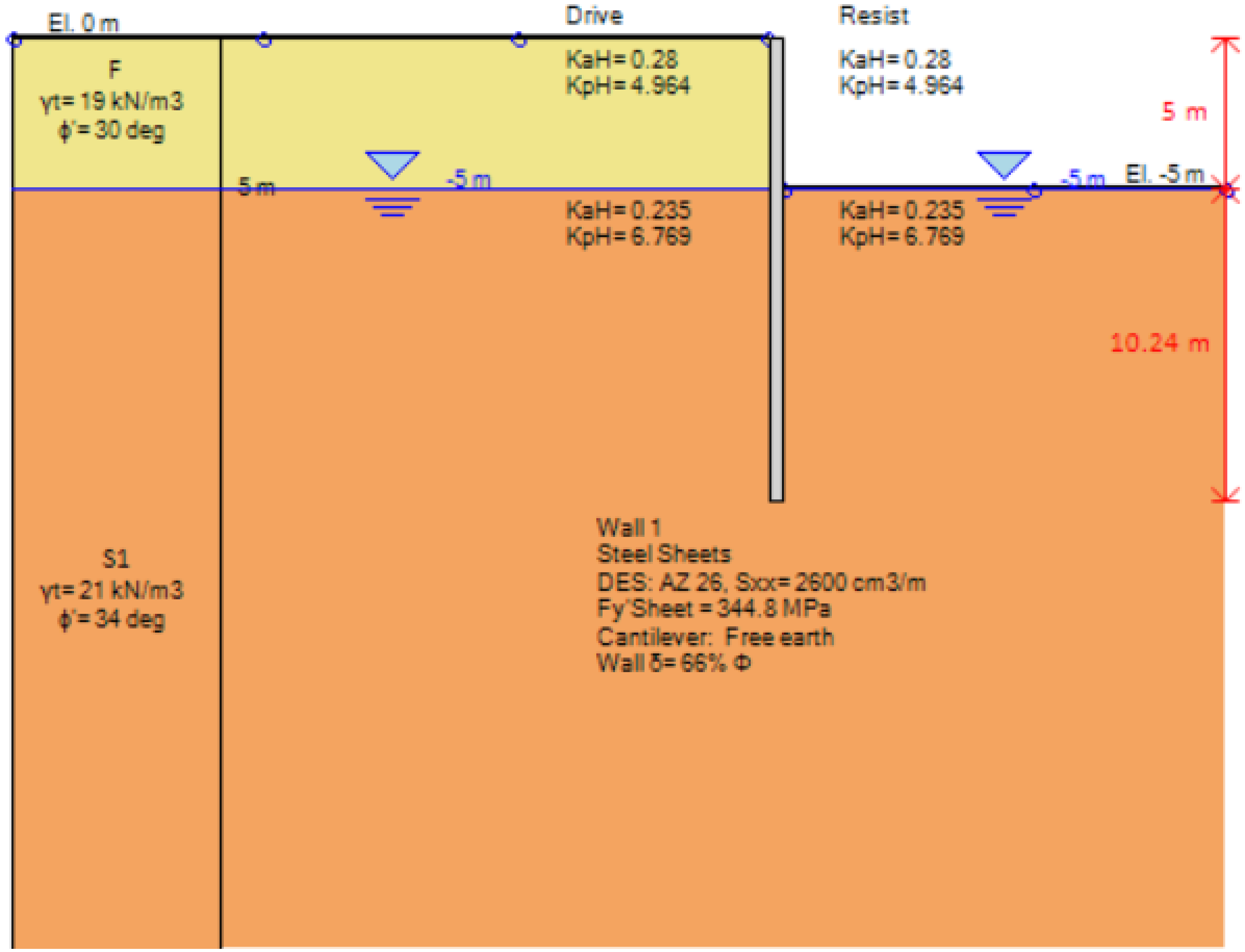
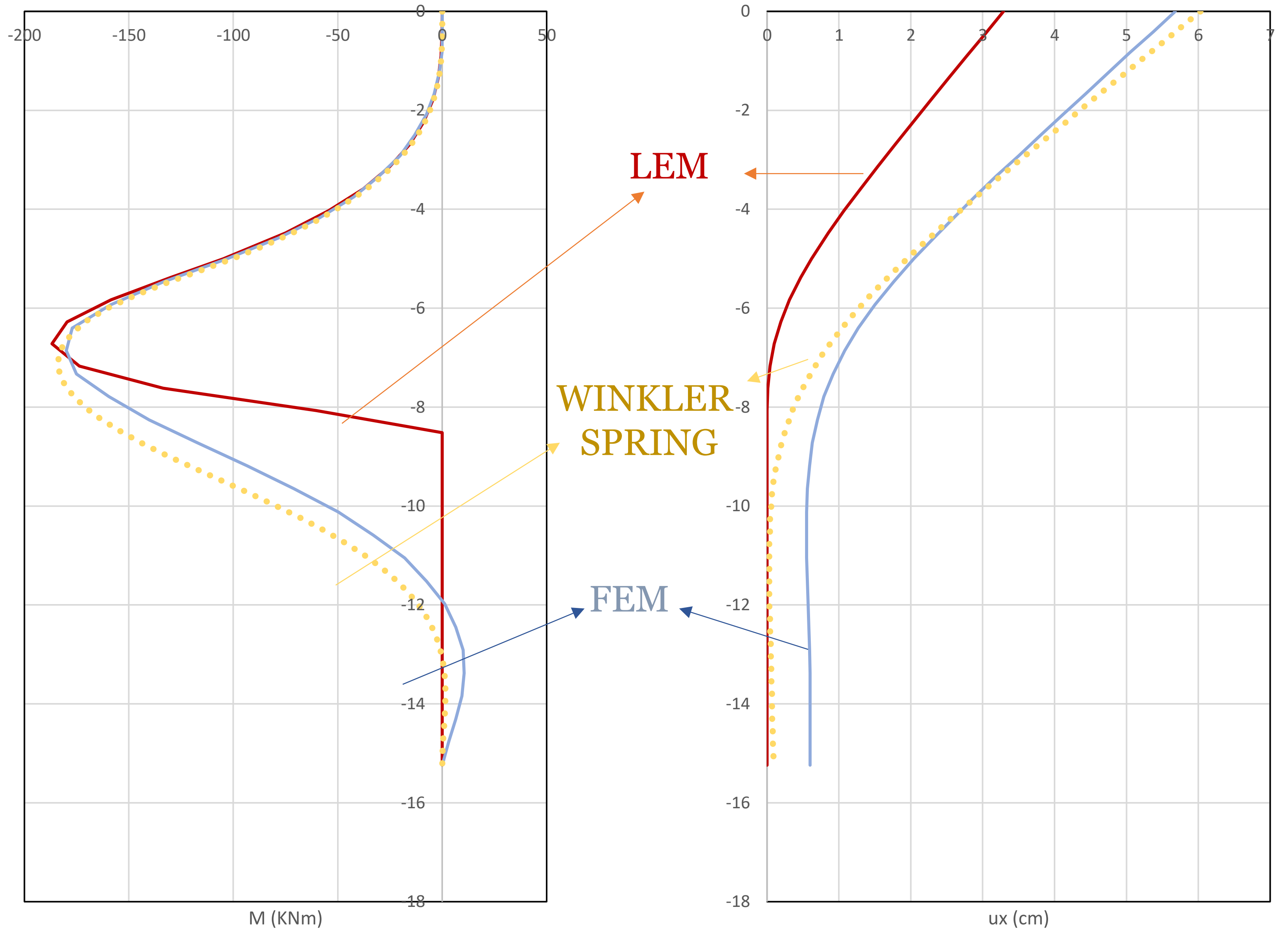




Active pressure

Earth Coefficients in DeepEX





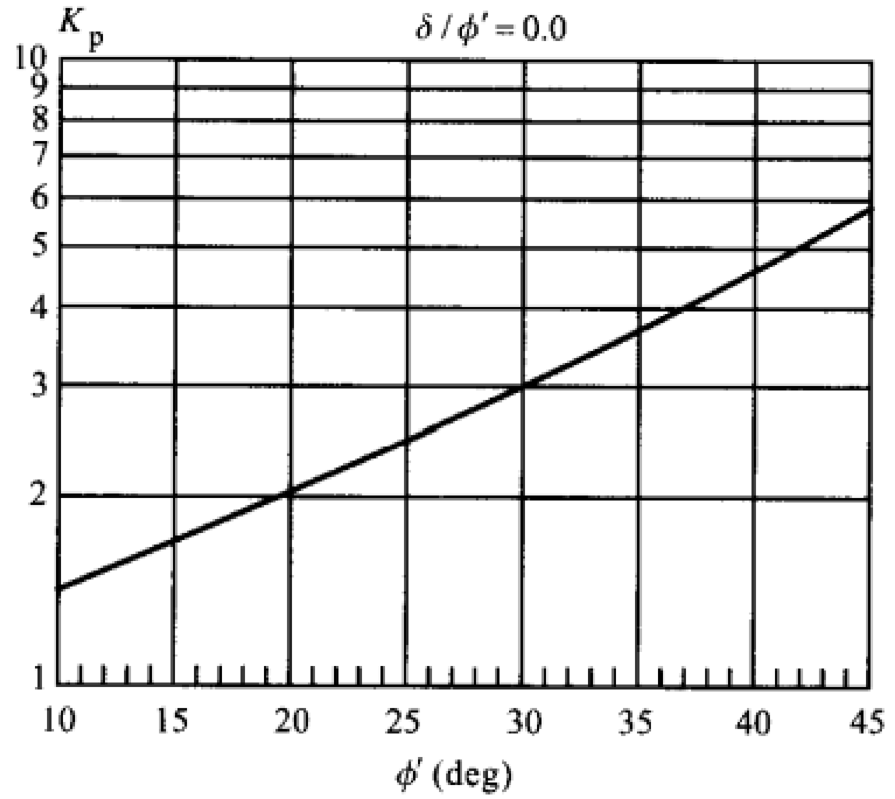
Displacements and moments on the wall

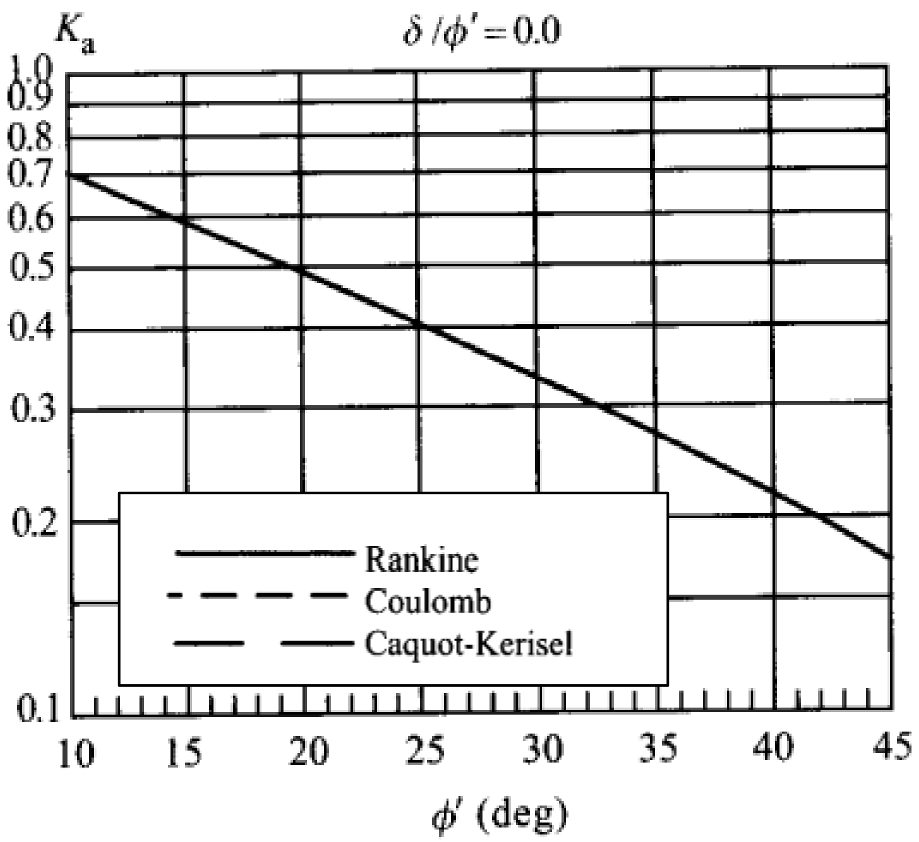
Earth Coefficients in DeepEX

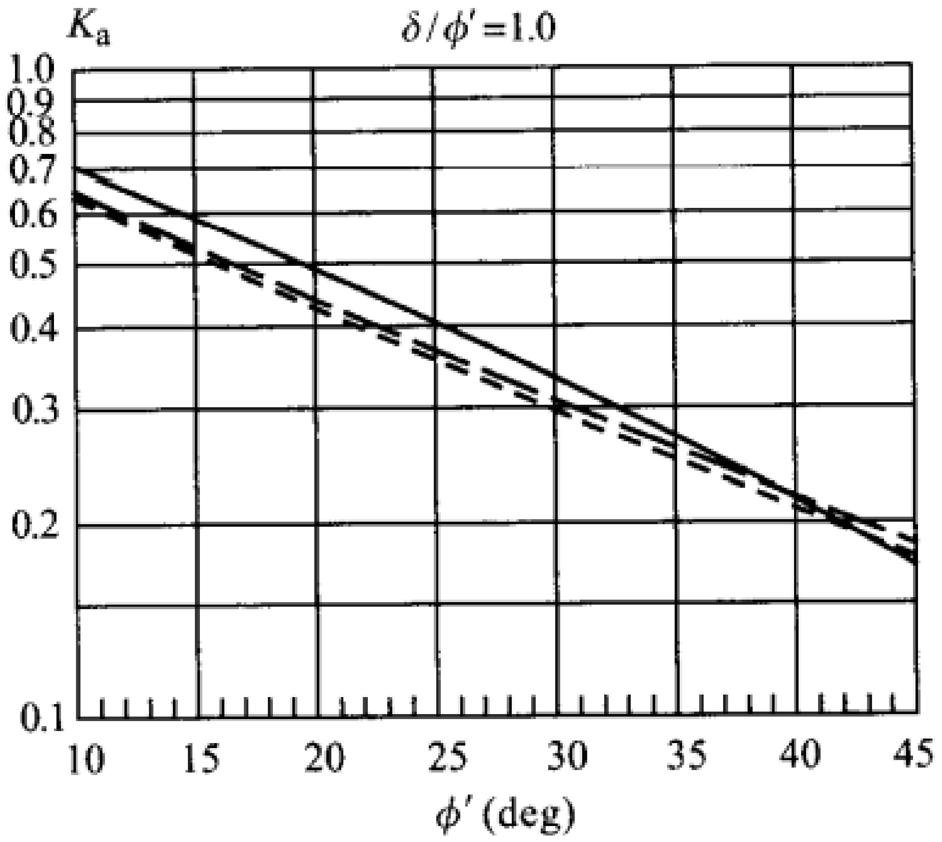
Earth pressure theories comparison:

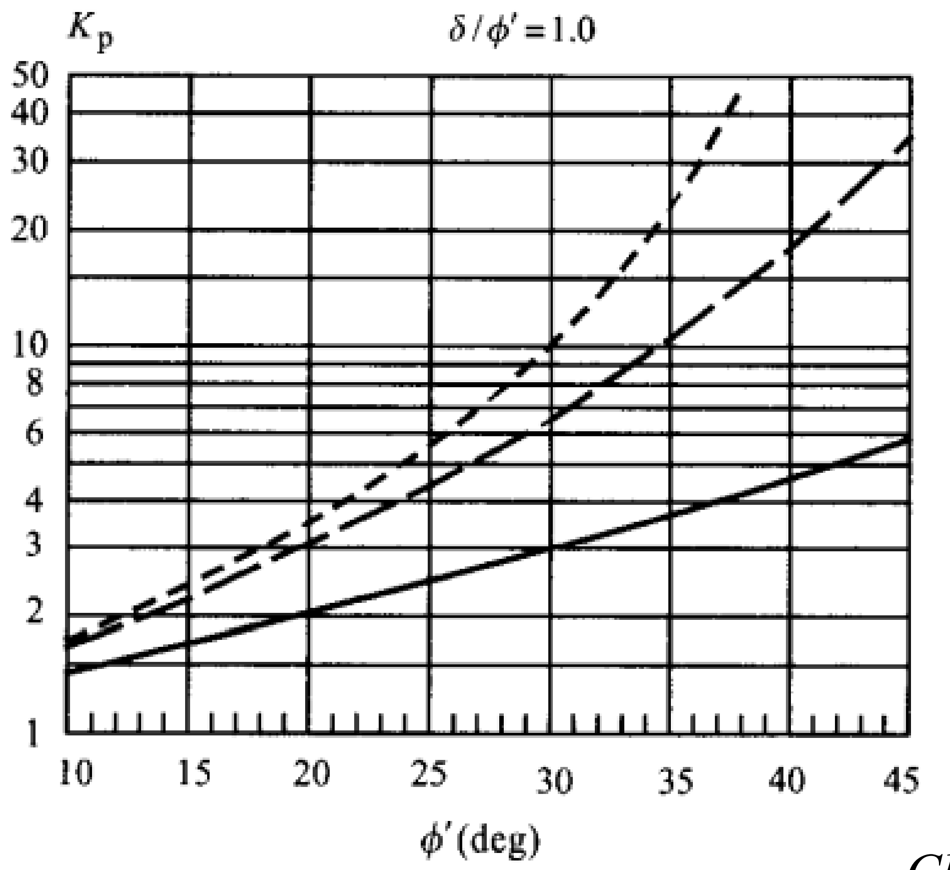
Differences are not that significant in Ka but mainly in Kp

δ=0 all methods identical, for δ>0 difference higher for higher δ







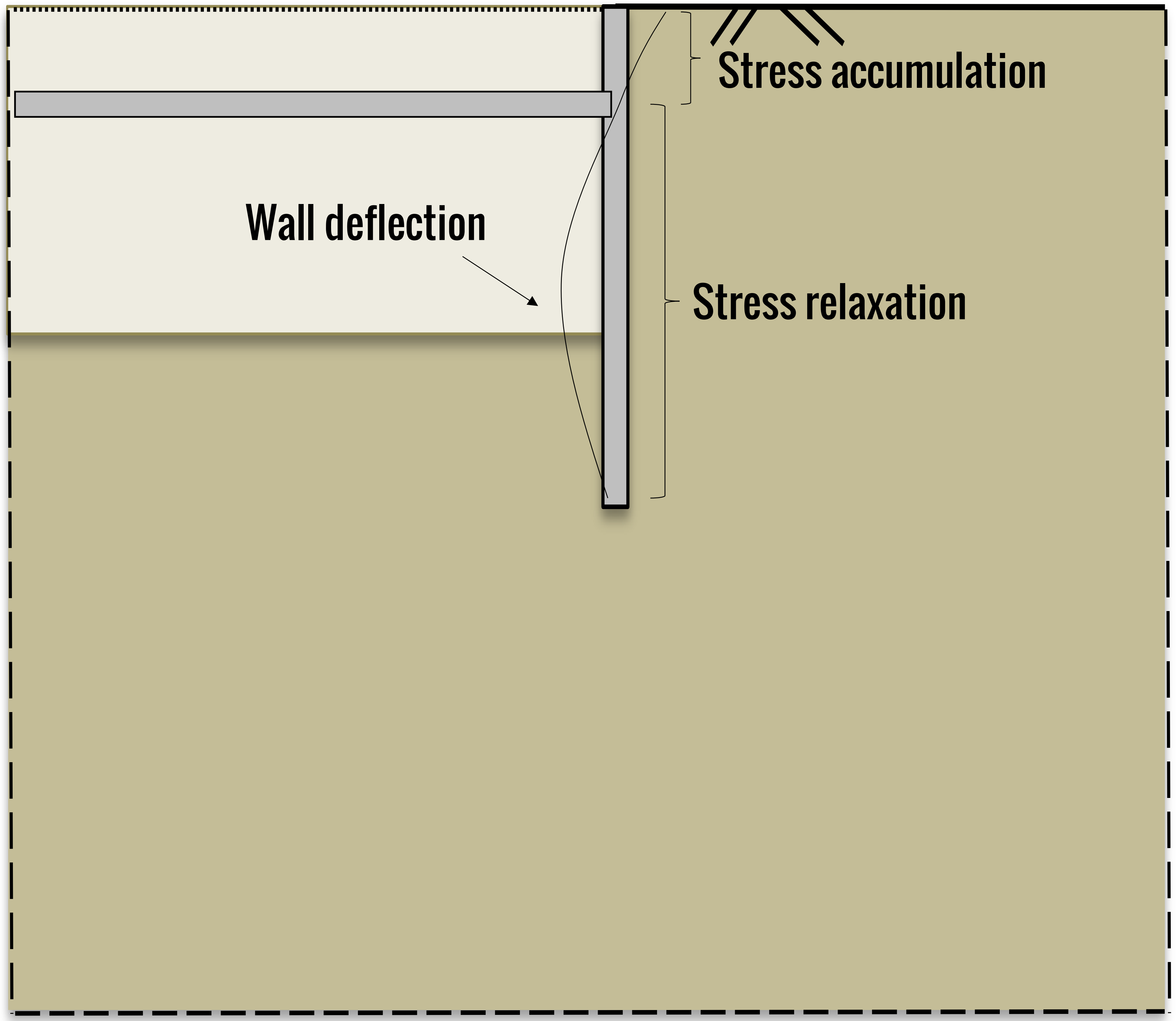


Chang-Yu Ou (2006)

Earth Coefficients in DeepEX

Apparent earth pressures

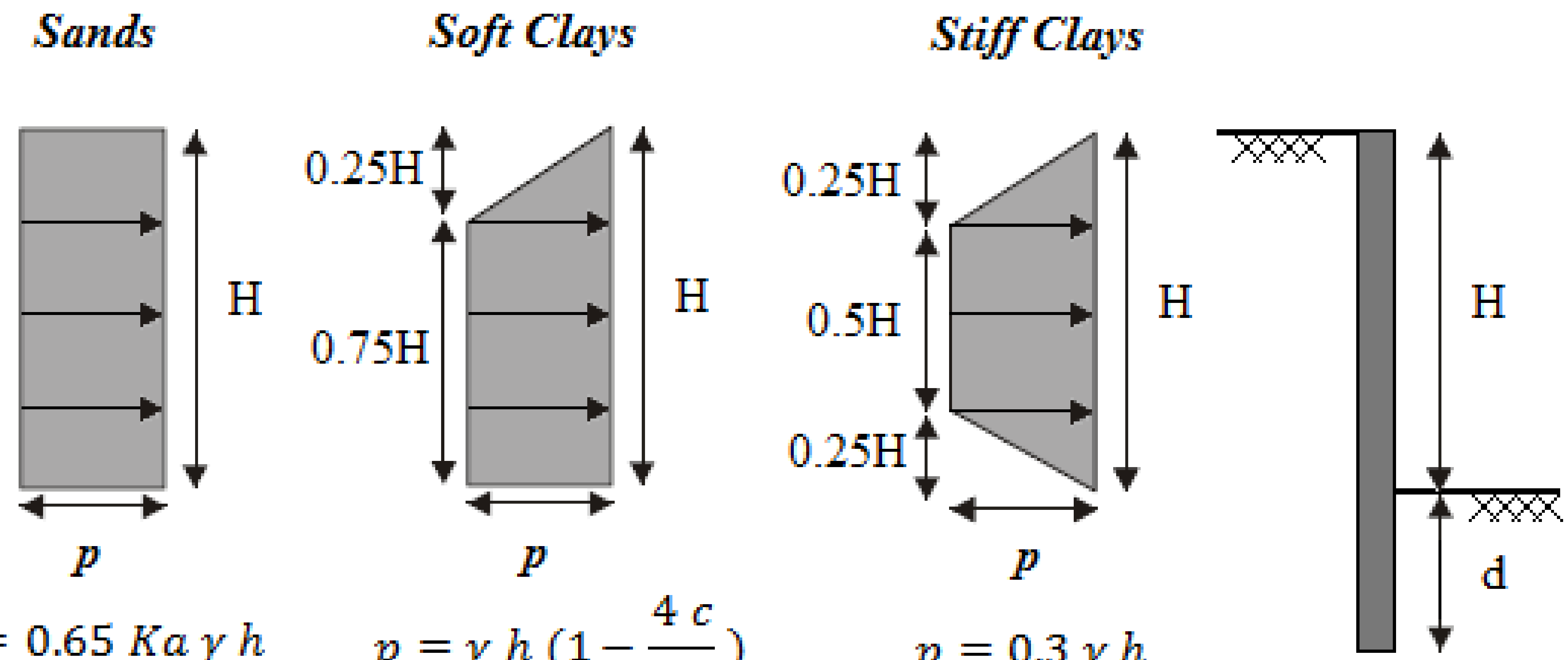
- Multilevel supported excavations experience different earth pressures
- effective active pressures multiplied by a factor and redistributed.



Earth Coefficients in DeepEX

Peck (1969) Method:

- based on multiple measurements of strut reactions of strutted excavations



$$p = 0.65\, Ka\, \gamma\, h$$

$$p = \gamma\, h\, (1 - \frac{4\, c}{\gamma\, h})$$

$$for\ \frac{4\, c}{\gamma\, h} > 1$$

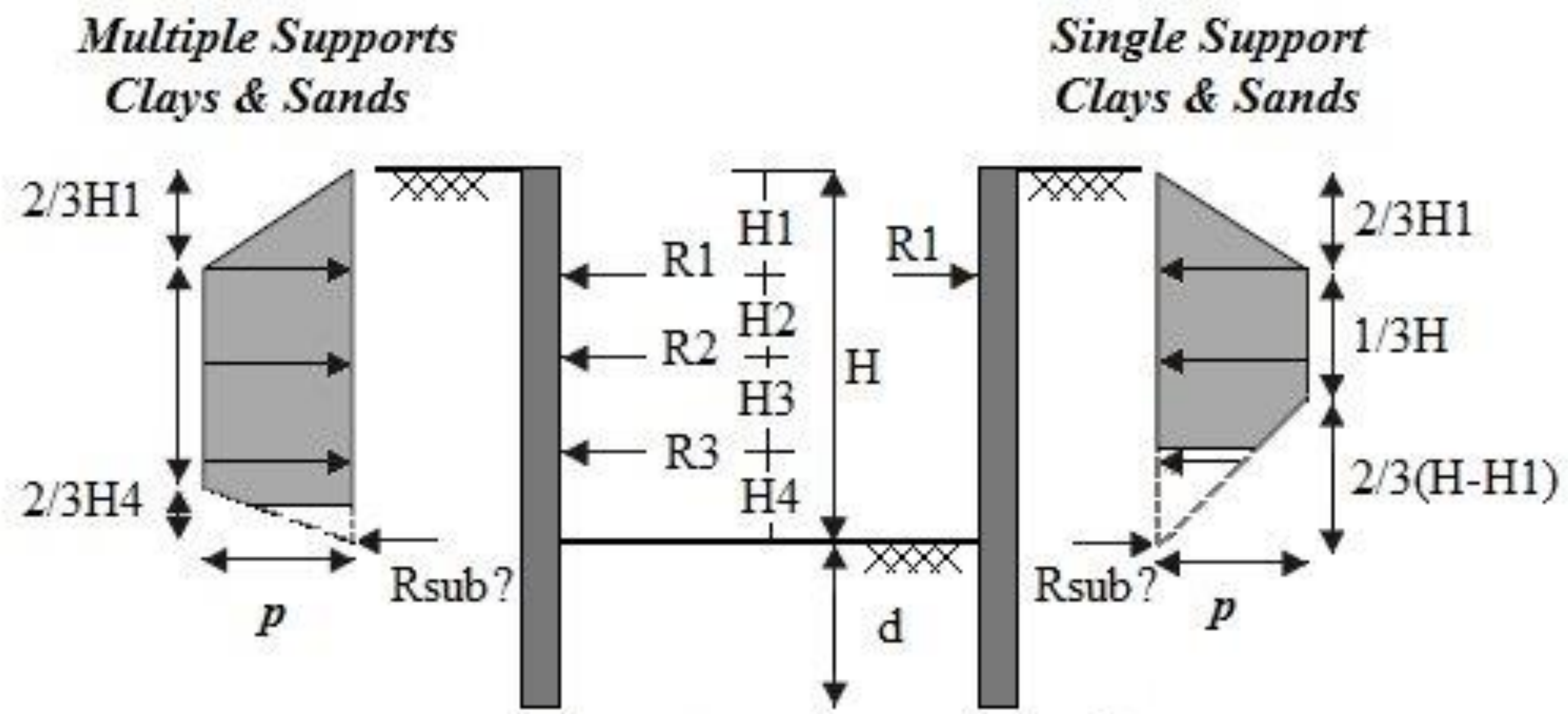
$$p = 0.3\, \gamma\, h$$

(Range 0.2 to 0.4)

Earth Coefficients in DeepEX

FHWA Method:

- based on multiple measurements of strut reactions of strutted excavations



Sands: Total Load = $0.65\, Ka\, \gamma\, h^2$

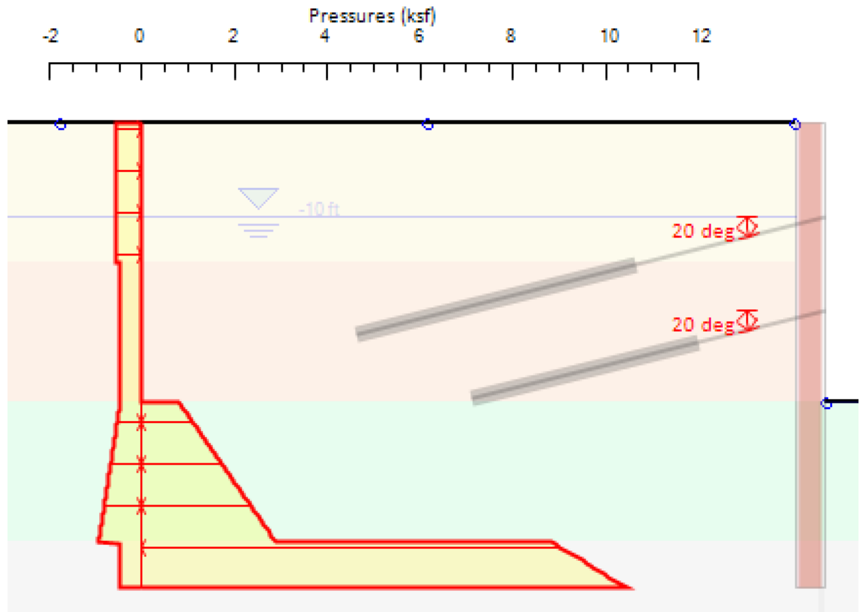
Clays: $p = 0.2\, \gamma\, h$ to $0.4\, \gamma\, h$

Rsub = Apparent virtual reaction at subgrade

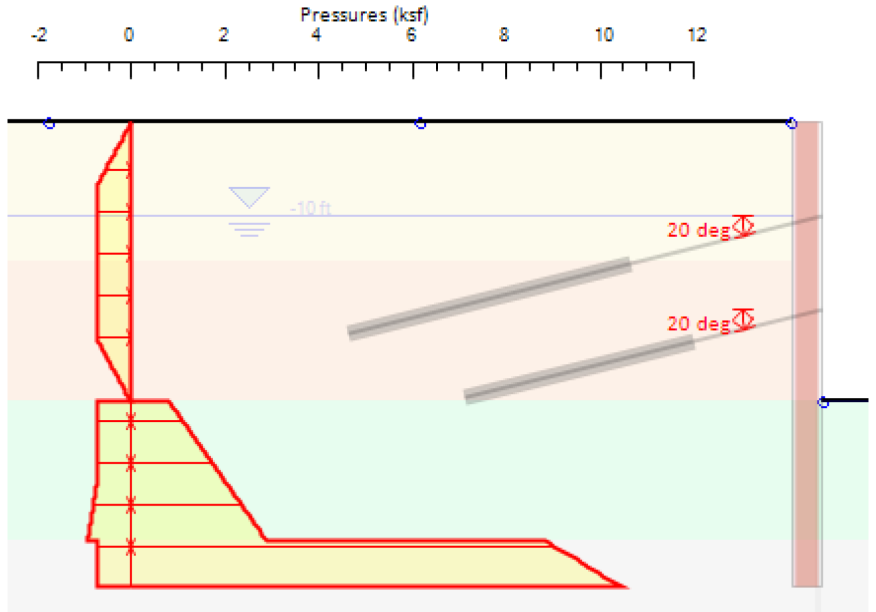
Soil Pressure Methods (LEM Analysis)

Construction Stages with multiple support levels

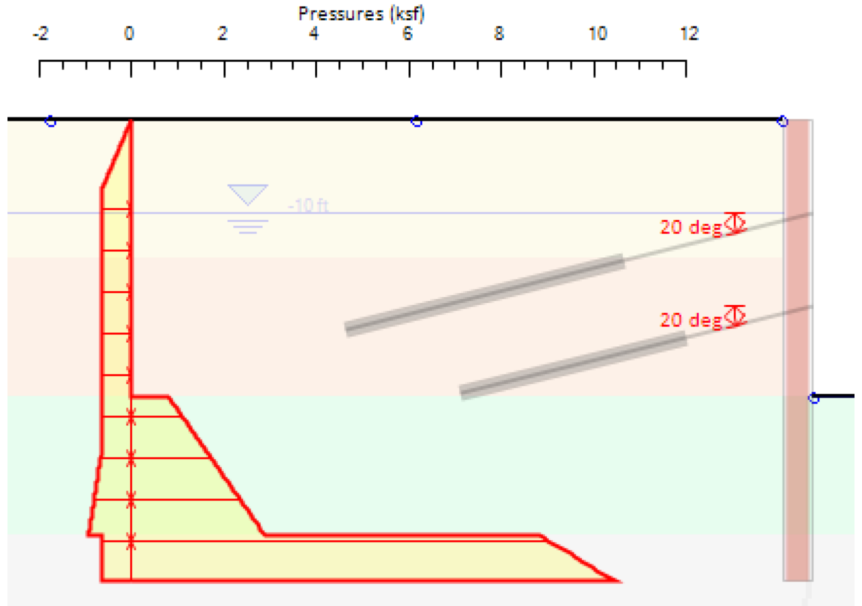
Peck 1969 Pressures



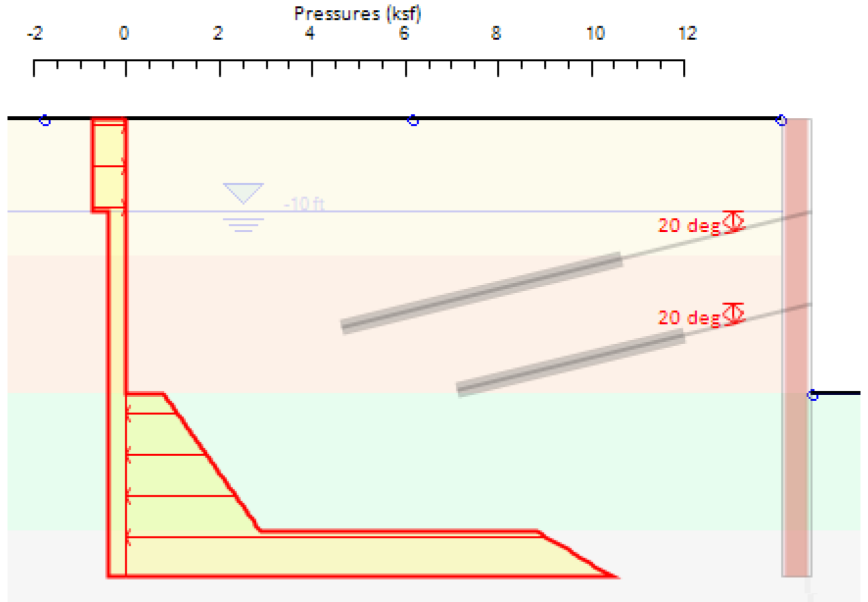
FHWA Apparent Pressures



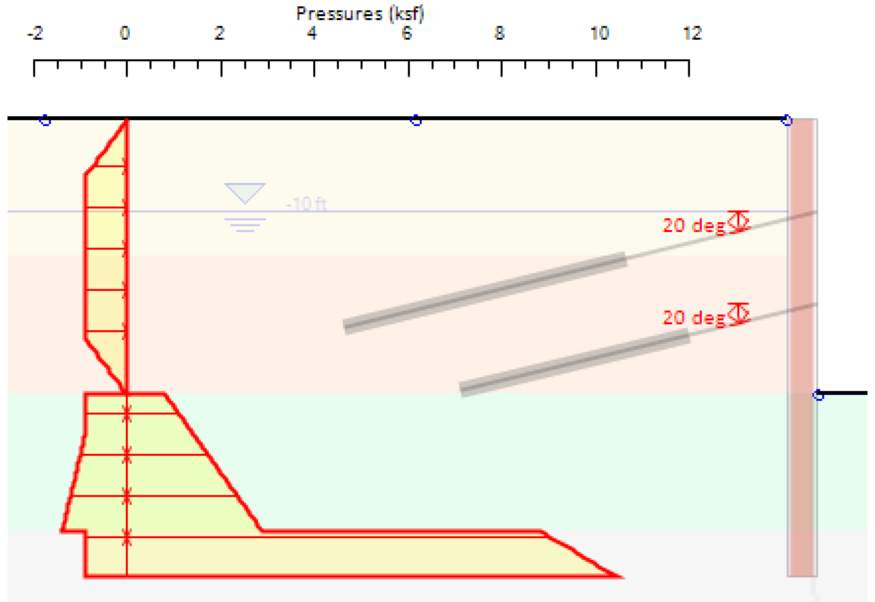
Custom Trapezoidal Pressures



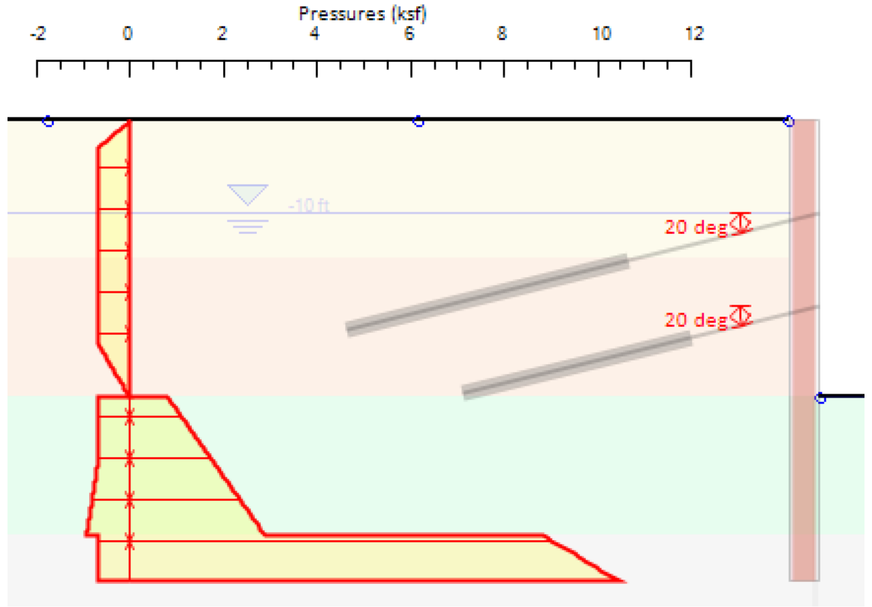
Two-Step Rectangular Pressures



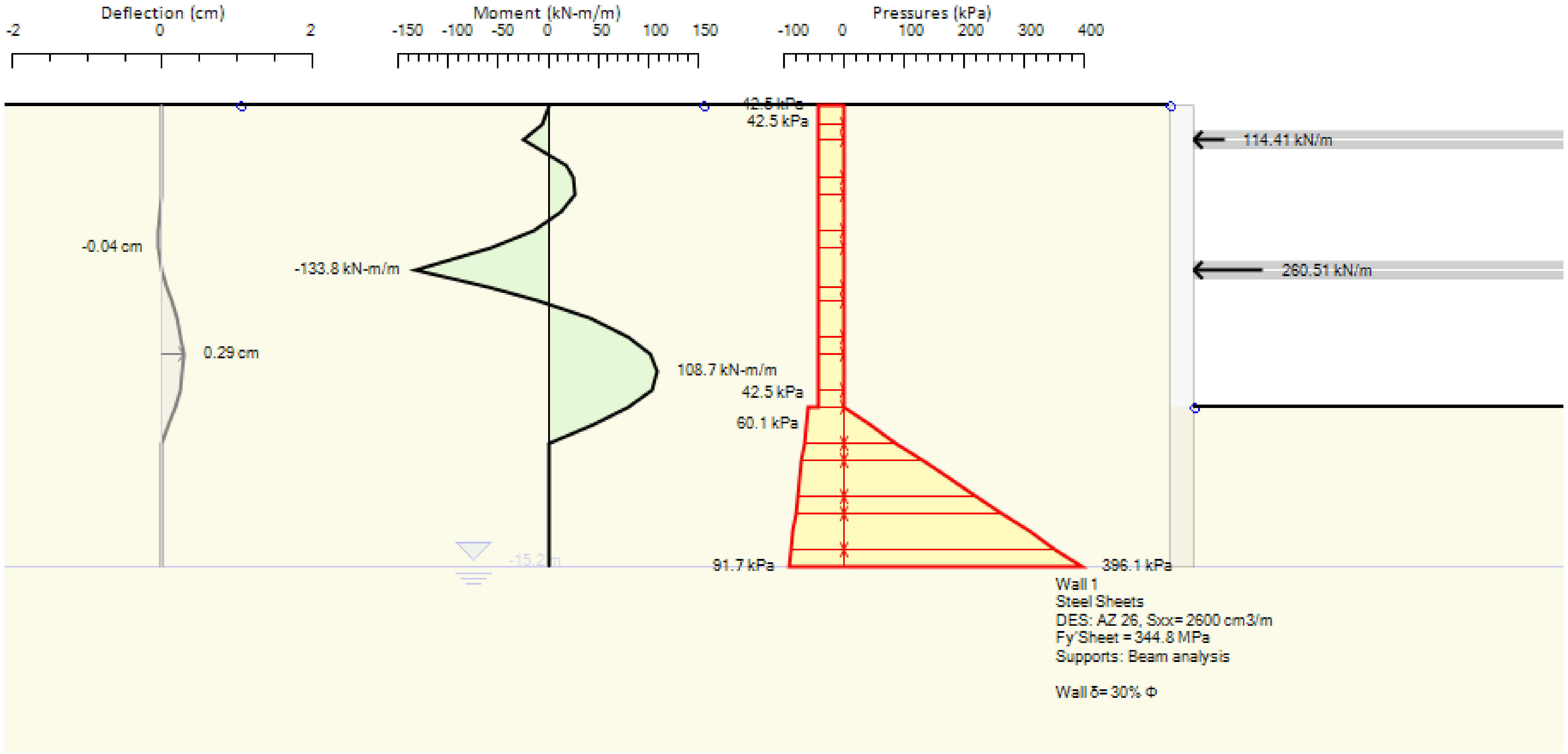
WMATA Pressures



New York City DEP Pressures

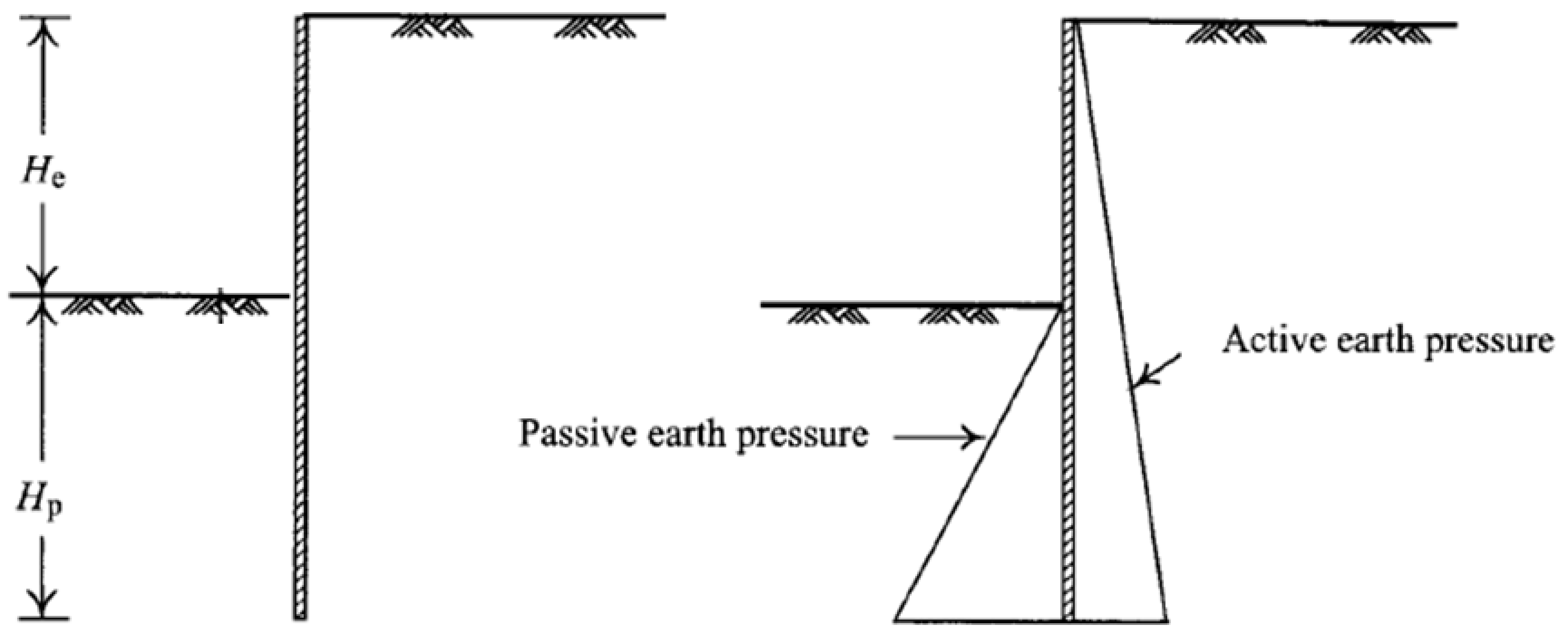


Example 2:

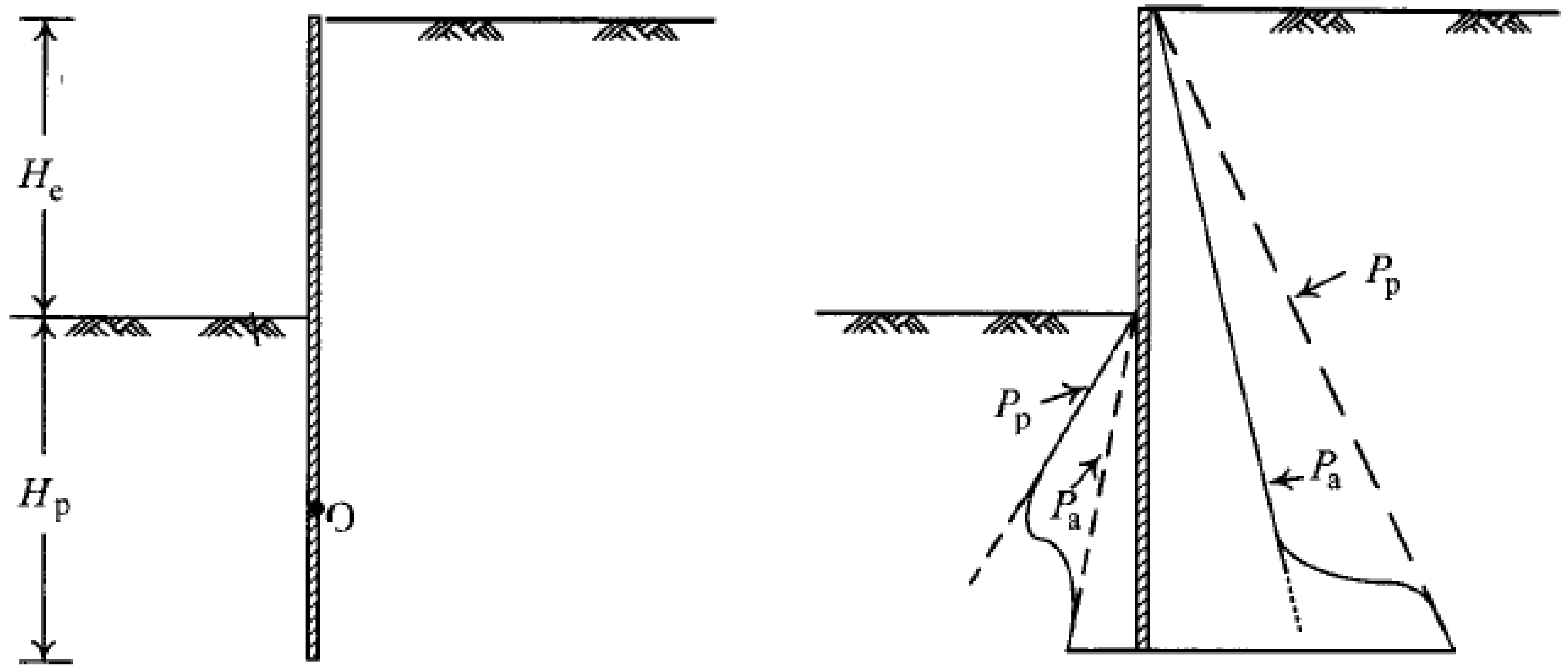

Deflection (cm)
-2
0
2
Moment (kN-m/m)
-150
-100
-50
0
50
100
150
Pressures (kPa)
-100
0
100
200
300
400
42.5 kPa
42.5 kPa
114.41 kN/m
260.51 kN/m
-0.04 cm
-133.8 kN-m/m
0.29 cm
108.7 kN-m/m
42.5 kPa
60.1 kPa
91.7 kPa
396.1 kPa
Wall 1
Steel Sheets
DES: AZ 26, Sxx= 2600 cm3/m
Fy'Sheet = 344.8 MPa
Supports: Beam analysis
Wall δ= 30% Φ

Cantilever Wall Analysis Concepts

Free earth method

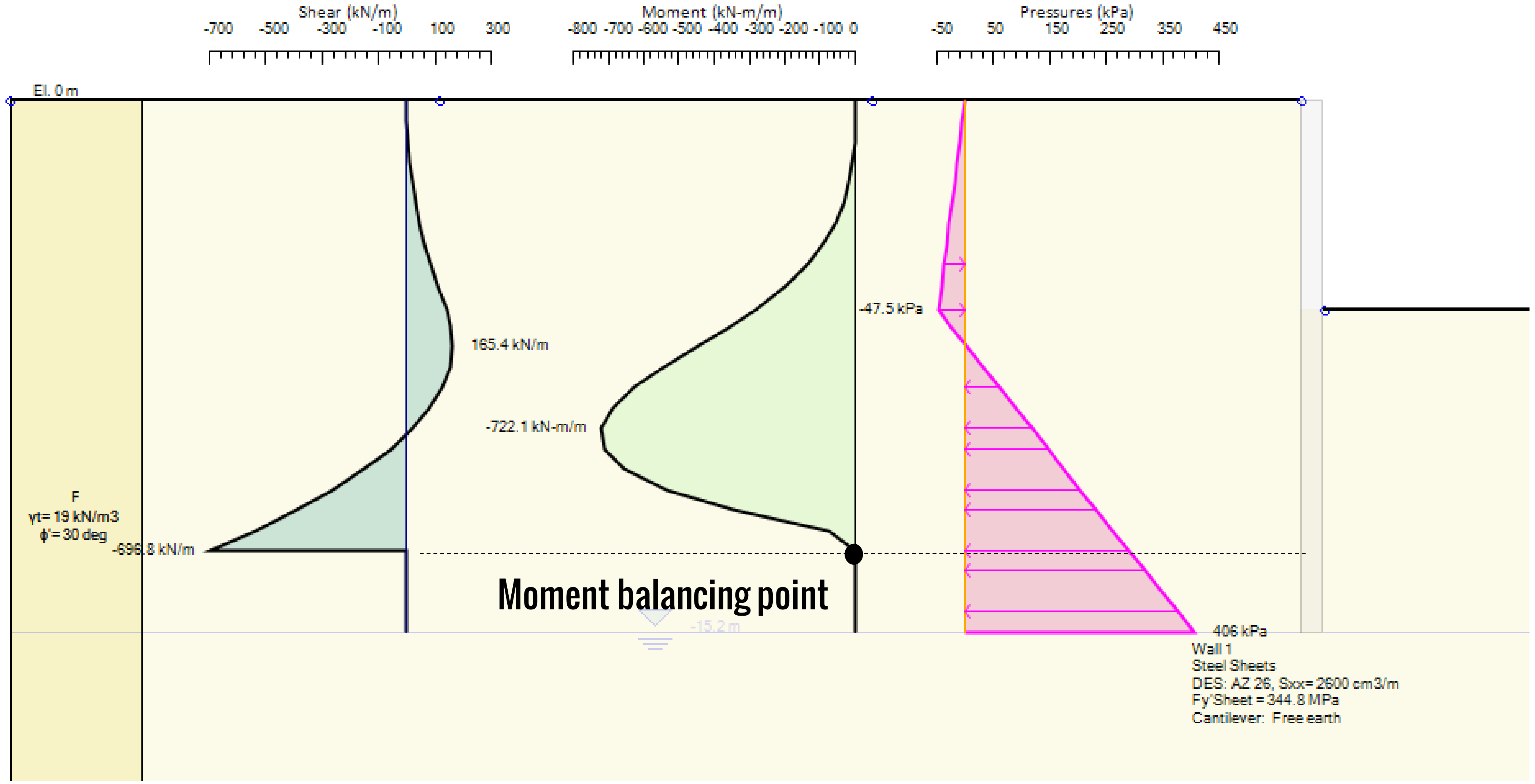


Fixed earth method



Free earth method

Balances out Moment - Shear not balanced

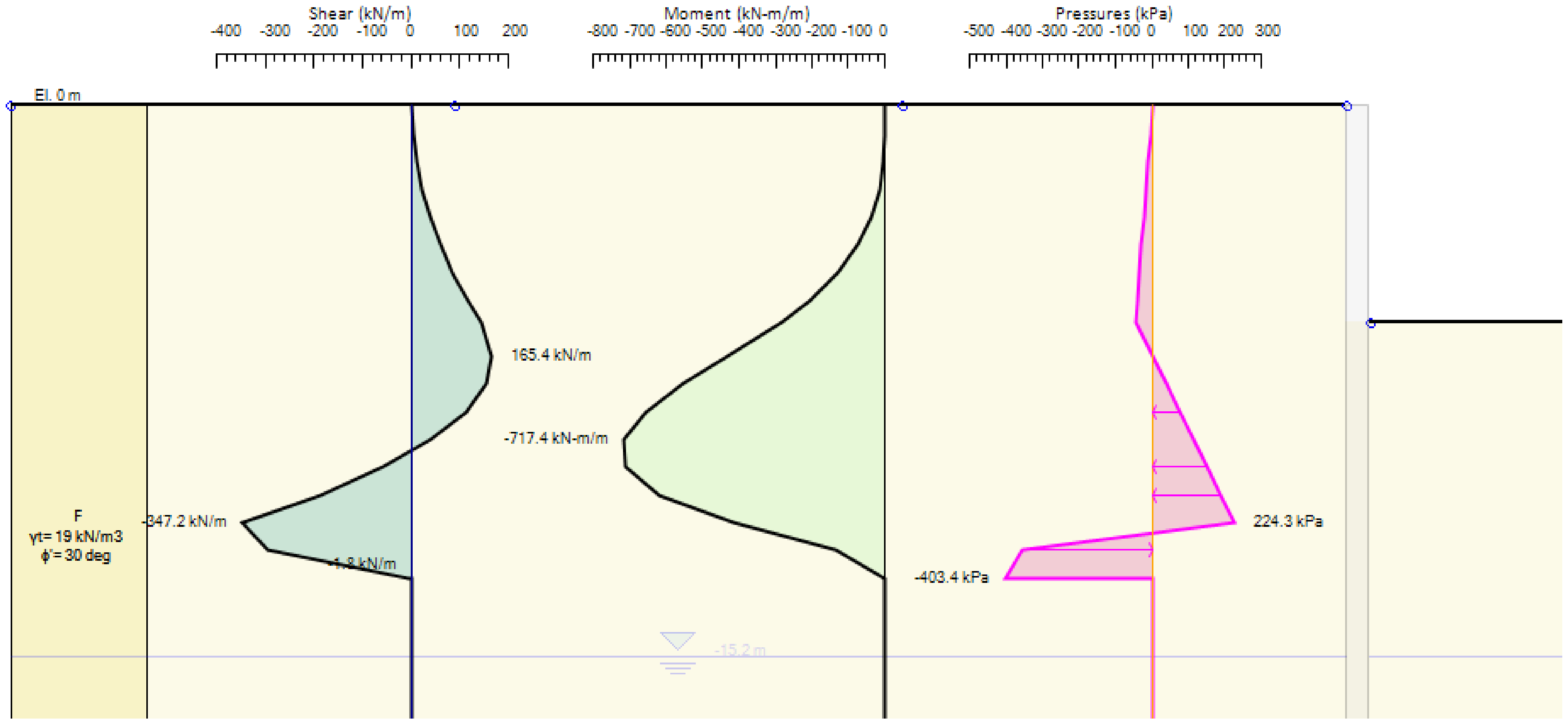


Cantilever Wall Analysis Concepts

Fixed earth method

Reversal of active-passive stress bellow pivot point

Comparison with advanced methods is recommended



Beam analysis - multiple supports

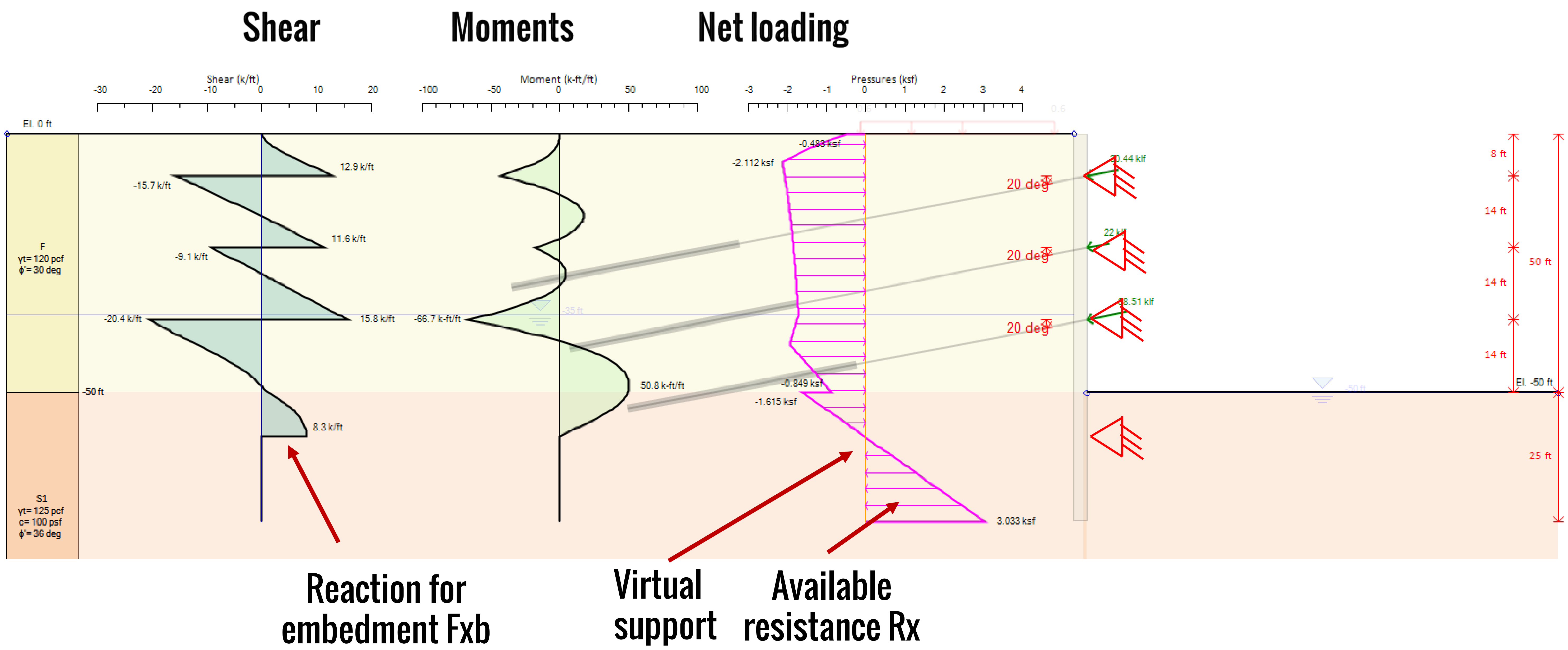
- Blum's method
- FHWA method with simple spans (GEC-4)
- Mix between FHWA and Blum's
- CALTRANS Trenching and Shoring Manual

Beam Analysis: Blum's Method

Pinned supports - continuous beam

Point of zero net soil shear below subgrade.

Use point of zero shear as a virtual support.



Conservative approximation of reactions, but non conservative calculation of Moment !!

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Beam Analysis: FHWA Simple Span Method

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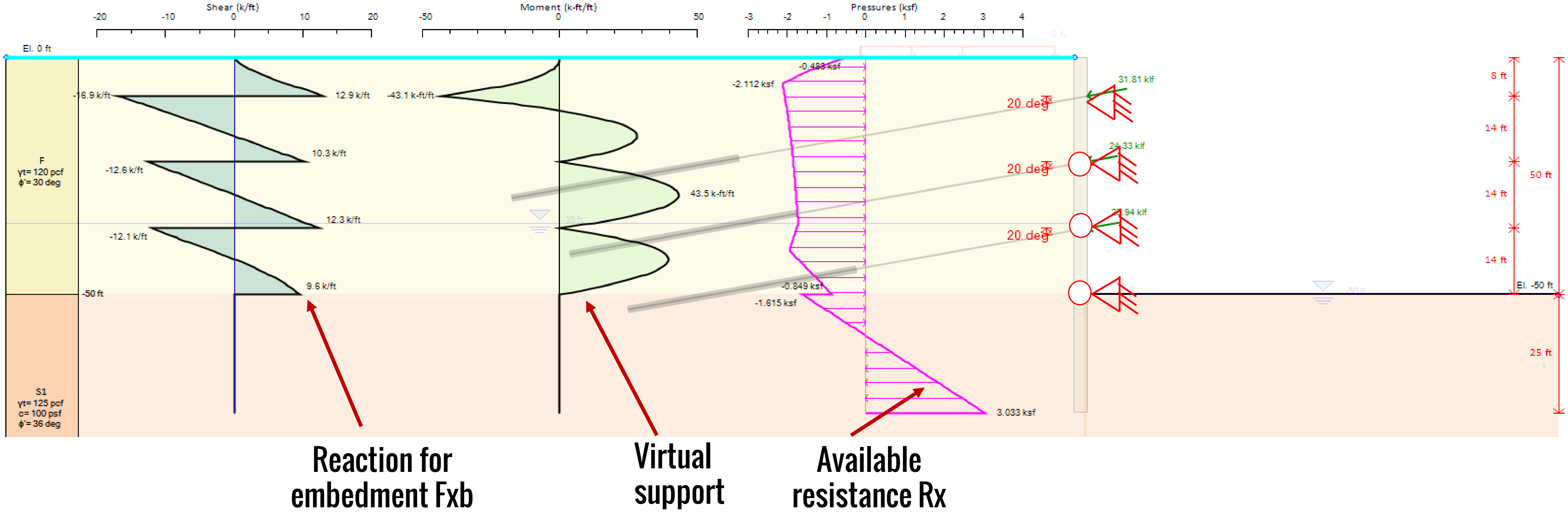
Pin support at excavation base, simple spans



Lower support reactions, no negative moments, but higher positive moments

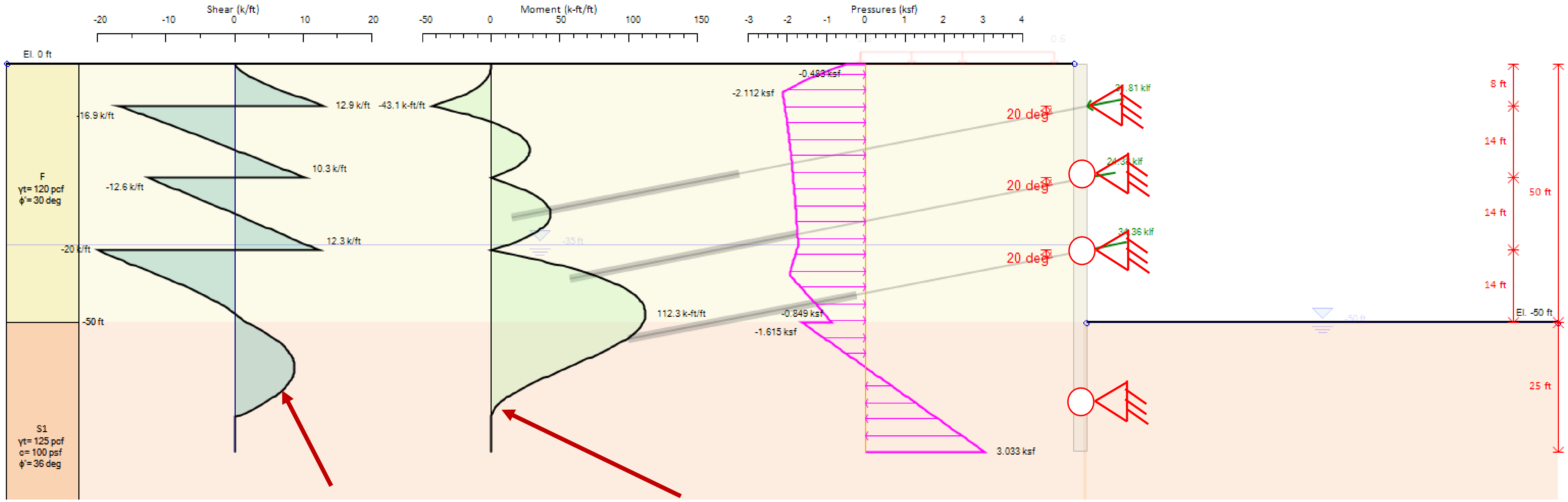
Beam Analysis: CALTRANS Approach

Pinned supports - simple span

Base at point of zero moment below bottom support

Shears and moments balance out

Shear Moments Net loading



No Embedment Reaction

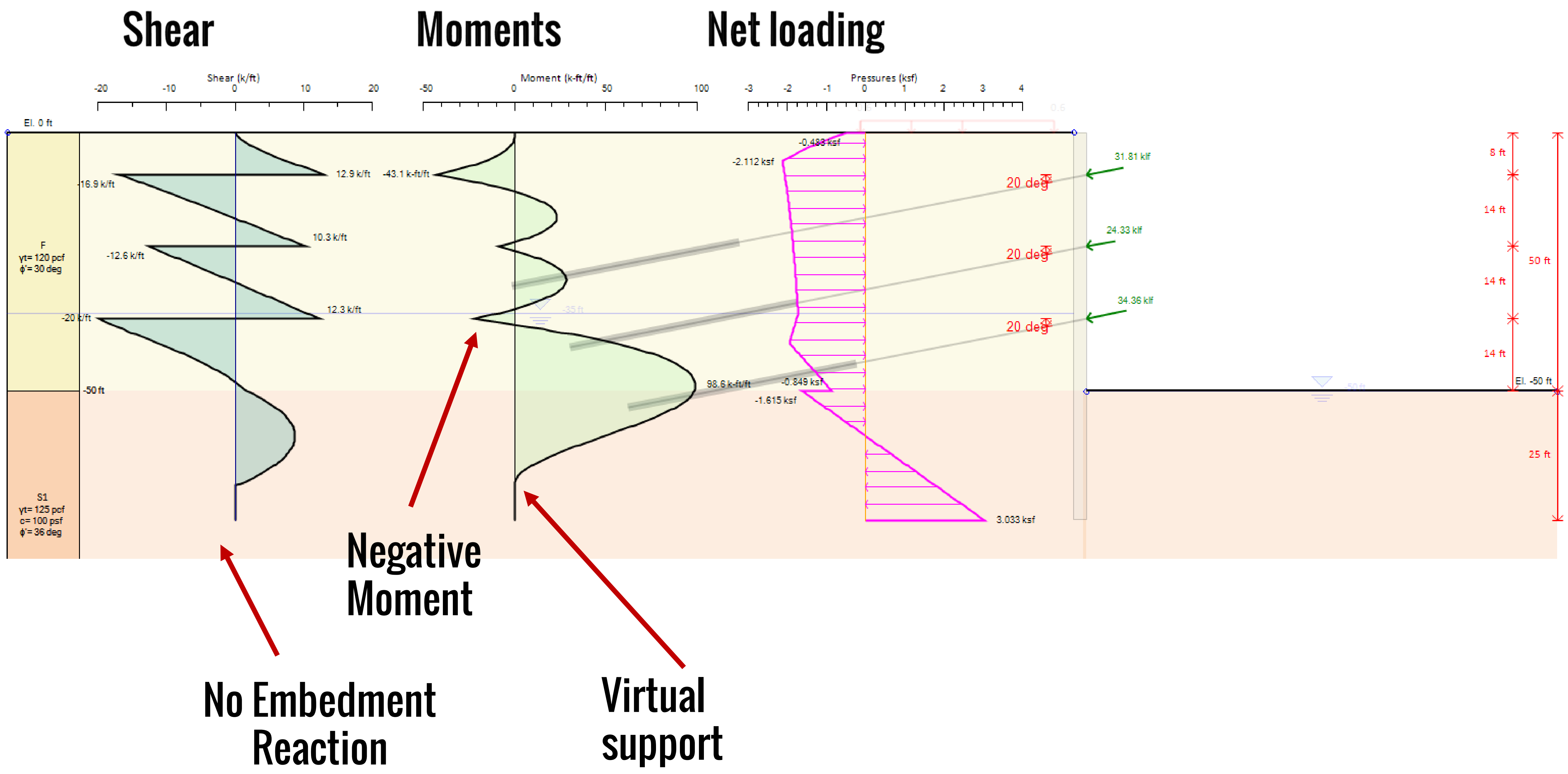
Virtual support

$$FS.rotation = \frac{Fresist}{Fdrive}$$

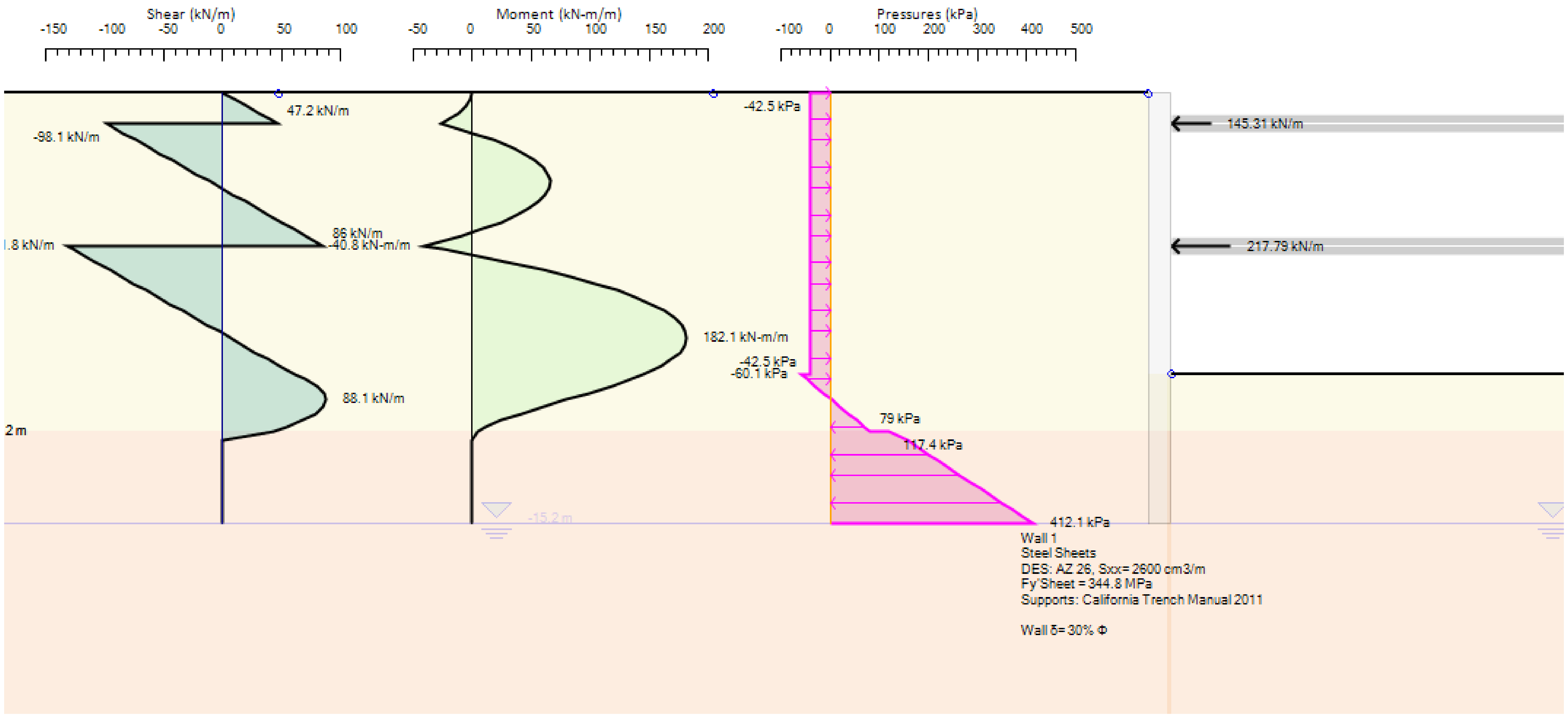
Lower support reactions, no negative moments, but higher positive moments

Beam Analysis: CALTRANS & negative moments

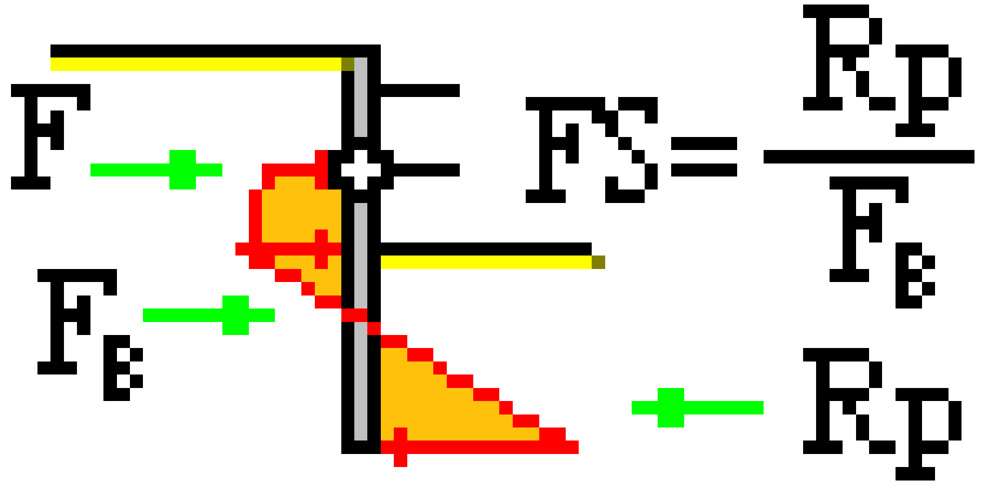
Simple span may be very conservative
Assume negative moments (20% of simple span)

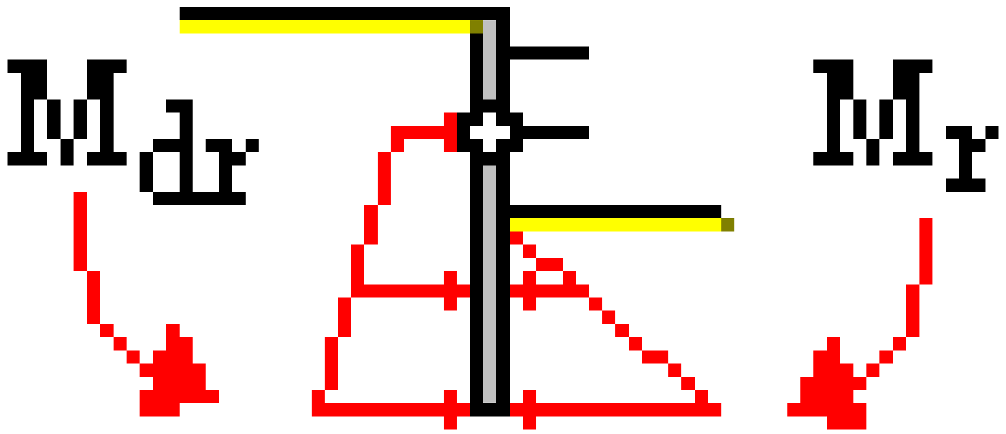


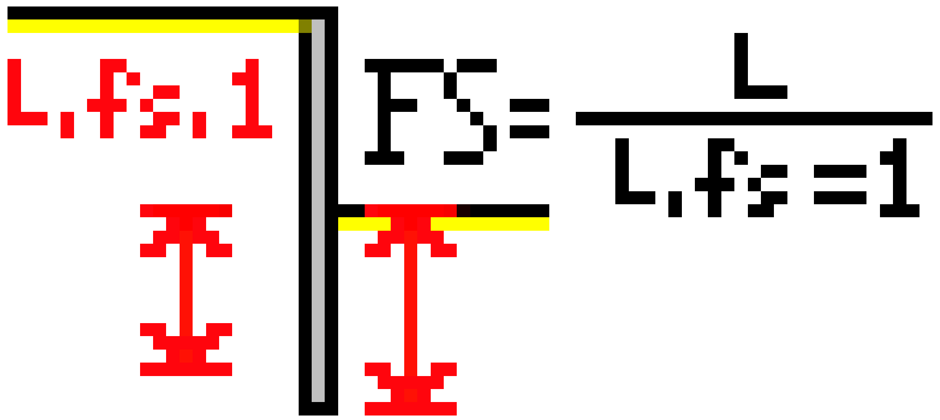
Example 3:


Shear (kN/m)
-150 -100 -50 0 50 100
Moment (kN-m/m)
-50 0 50 100 150 200
Pressures (kPa)
-100 0 100 200 300 400 500
47.2 kN/m
-98.1 kN/m
86 kN/m
-40.8 kN-m/m
.8 kN/m
88.1 kN/m
2 m
182.1 kN-m/m
-42.5 kPa
-42.5 kPa
-60.1 kPa
79 kPa
117.4 kPa
412.1 kPa
145.31 kN/m
217.79 kN/m
-15.2 m
Wall 1
Steel Sheets
DES: AZ 26, Sxx= 2600 cm3/m
Fy'Sheet = 344.8 MPa
Supports: California Trench Manual 2011
Wall δ= 30% Φ

Wall toe Stability checks







$$FSpas = \frac{Available\ Resistance\ beneath\ \mathrm{virtual}\ fixity\ point}{Hor.reaction\ at\ virtual\ point + driving\ pressures\ beneath\ virtual\ fixity\ point}$$

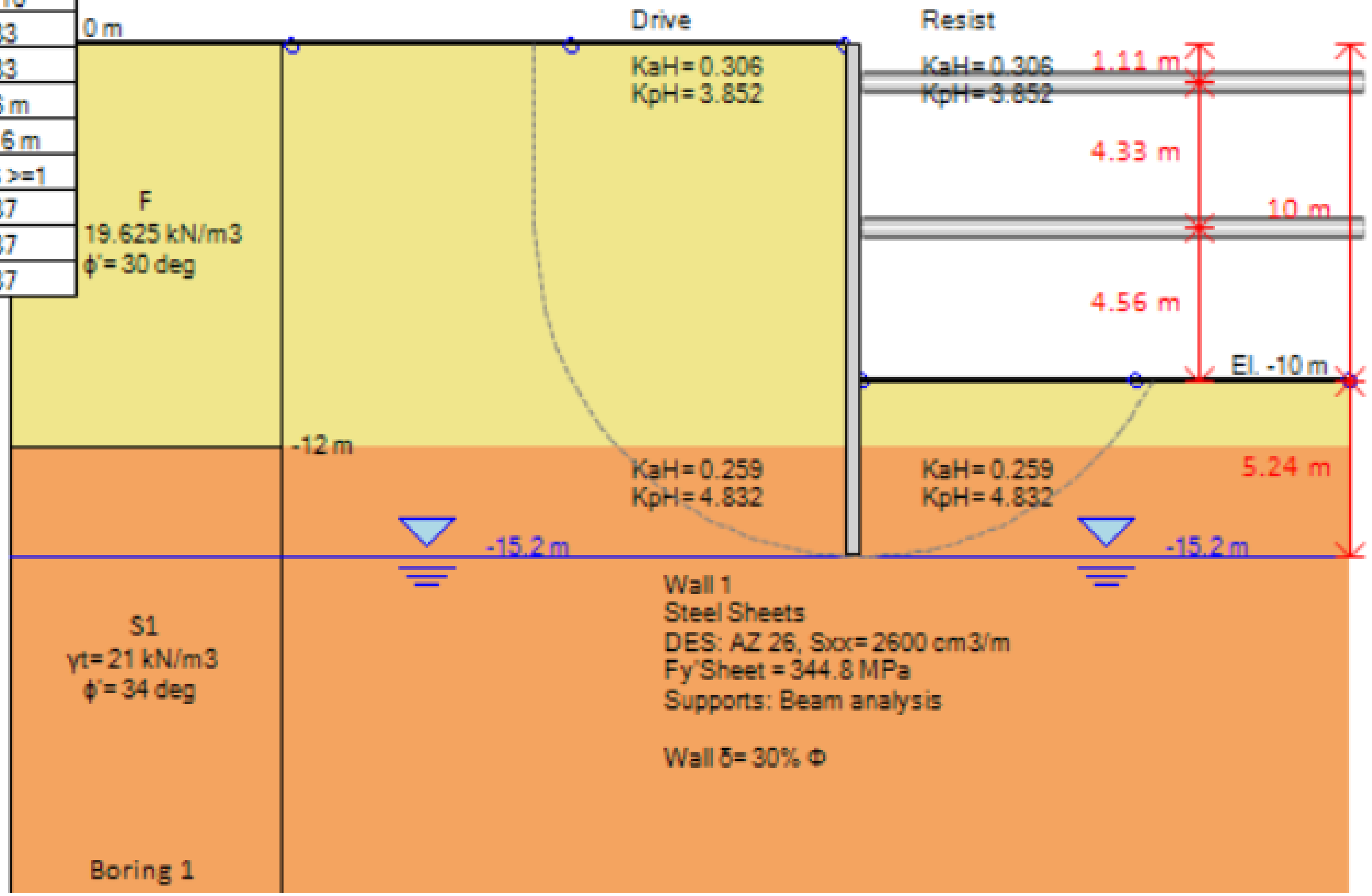
$$FSrotation = \frac{Resisting\ moments\ about\ a\ point}{Driving\ moments\ about\ the\ same\ point} \ (Eq.\,9.2)$$

$$FSembed = \frac{Available\ wall\ embedment\ depth}{Max.Required\ embedment\ depth\ for\ FS = 1\ from\ Equations\ 1\&\ 2\ above} \ (Eq.\,9.3)$$

Wall toe Stability checks

Example 4:

Wall Toe Safety:	Wall 1
Min FS=	2.262
FS Embed=	2.262
FS pas.=	10.616
FS Rot.=	3.333
FScircular=	2.533
Req. toe FS=1:	2.316 m
Toe El. FS=1:	-12.316 m
Note:	Toe FS >=1
FS Basal=	3.587
Basal standard	3.587
Basal standard	3.587

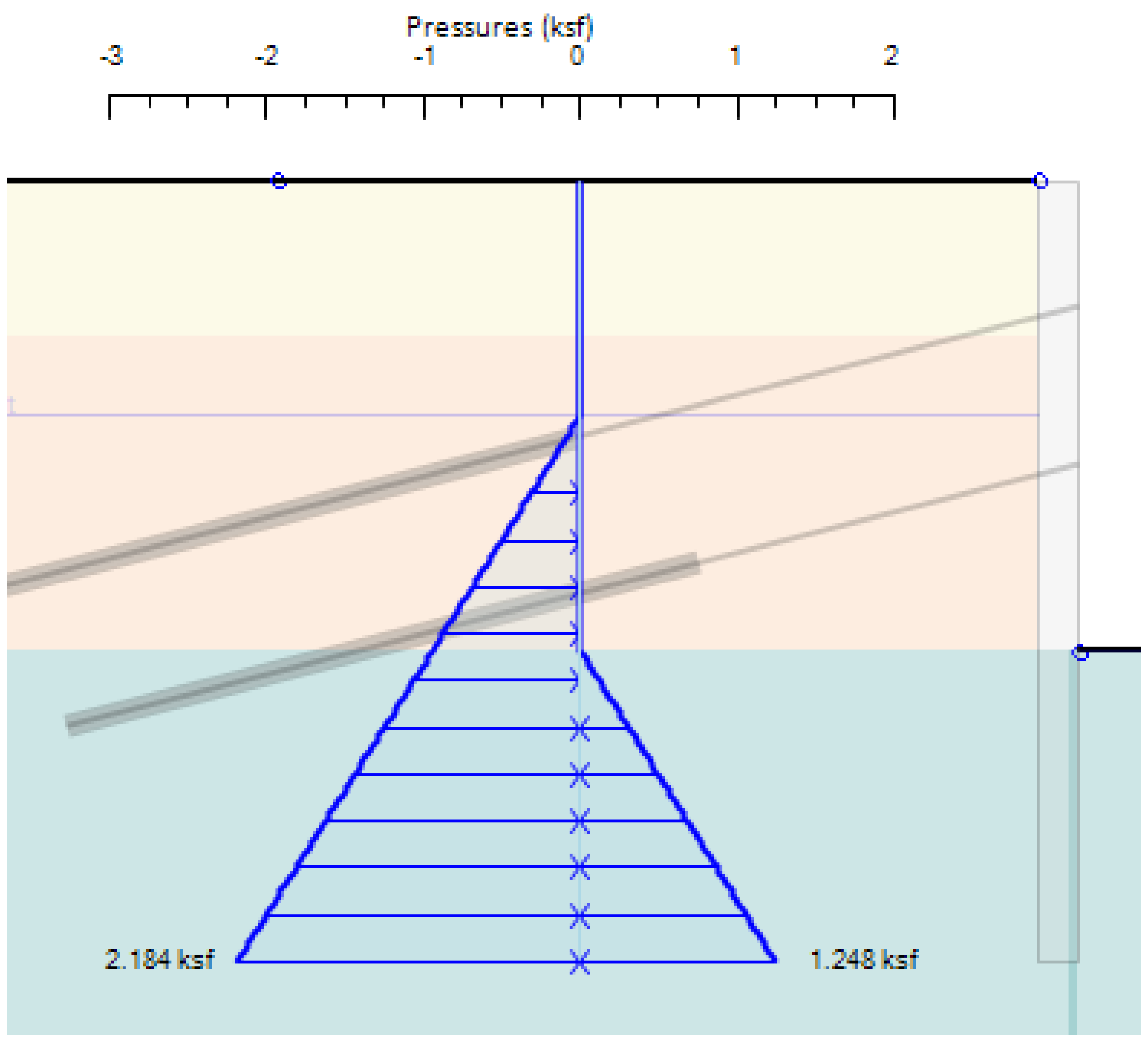


DeepEX
Shoring Design Software

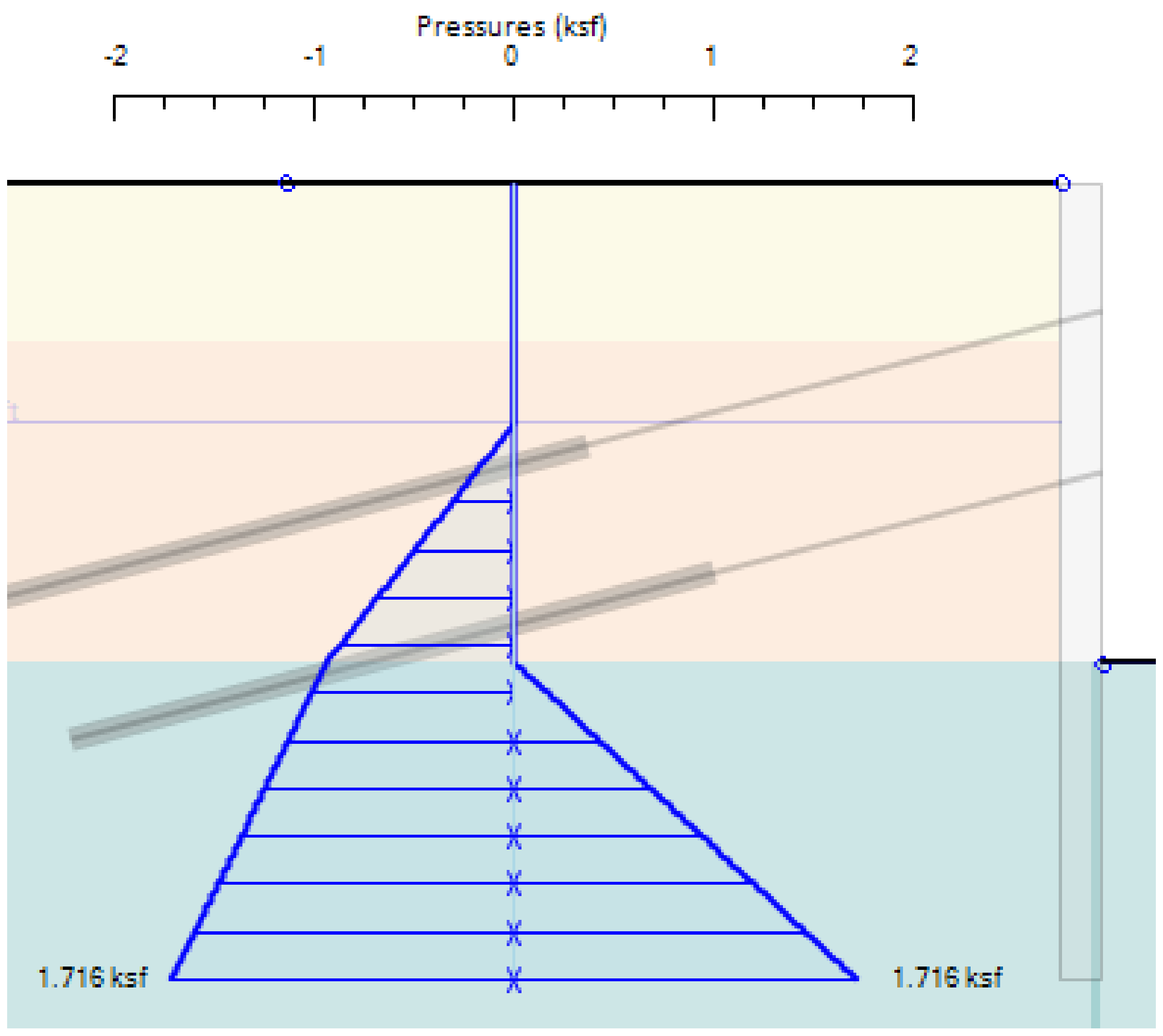
Water Pressure Methods

www.deepexcavation.com

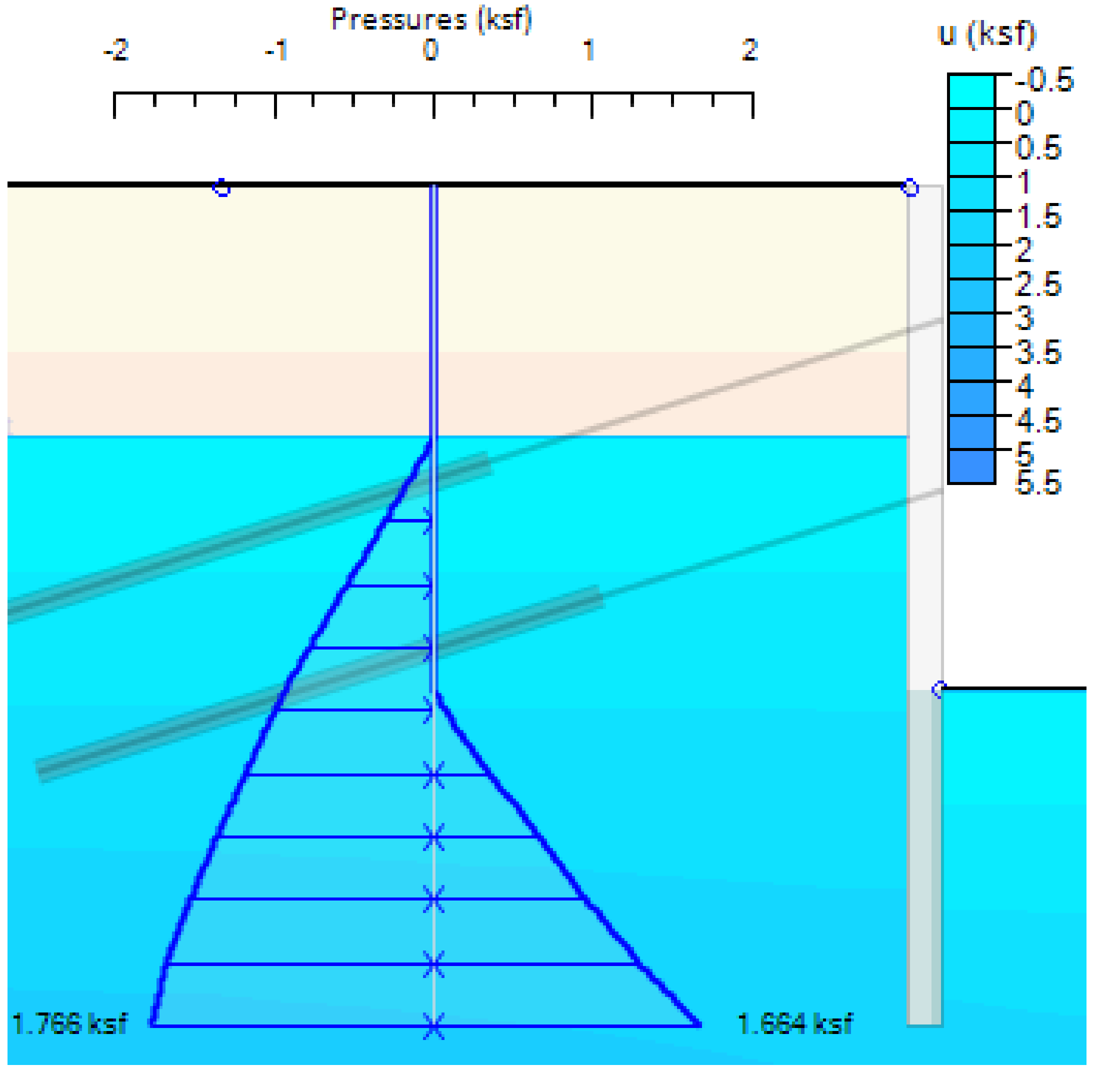
Hydrostatic



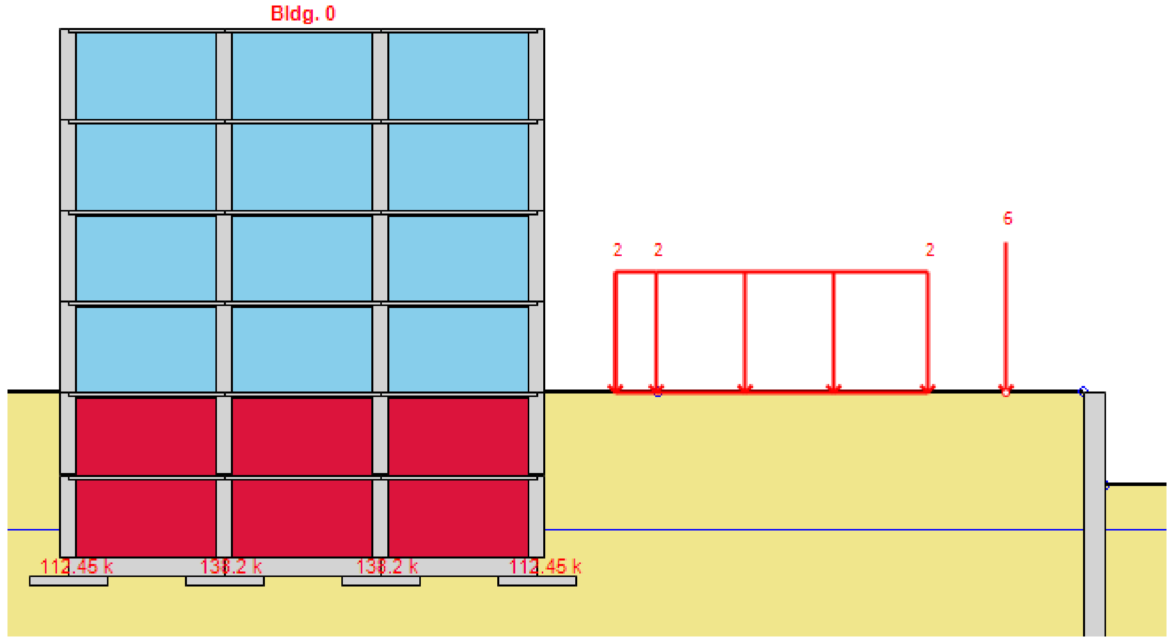
Simplified Flow

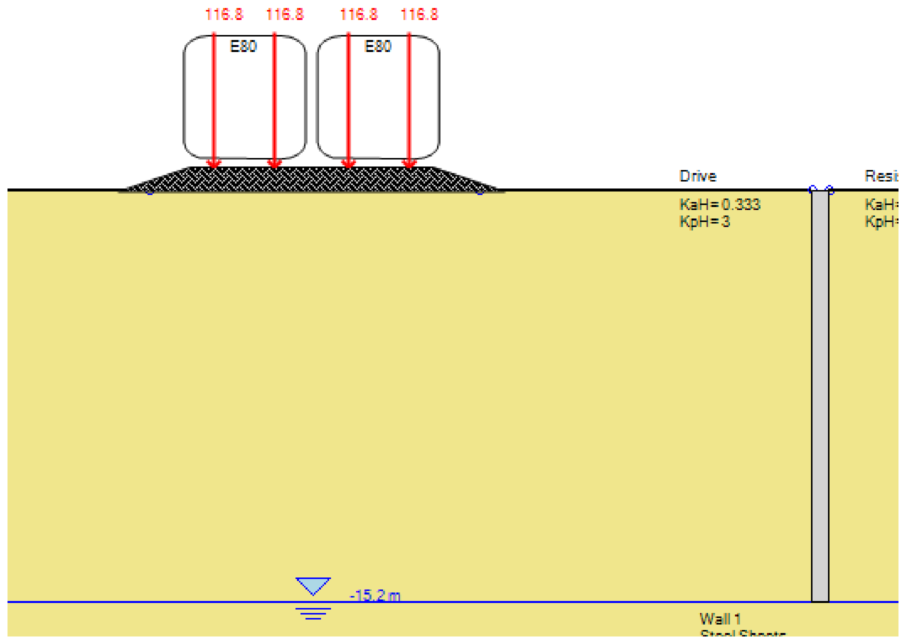


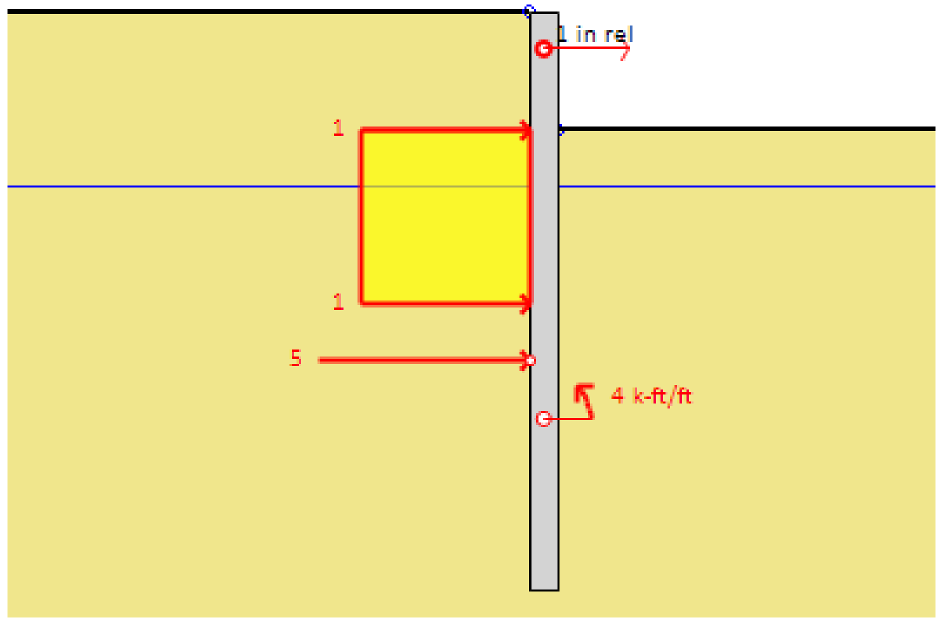
Full Flownet Analysis



External Loads: Types & Pressure Methods







Loads on ground surface:

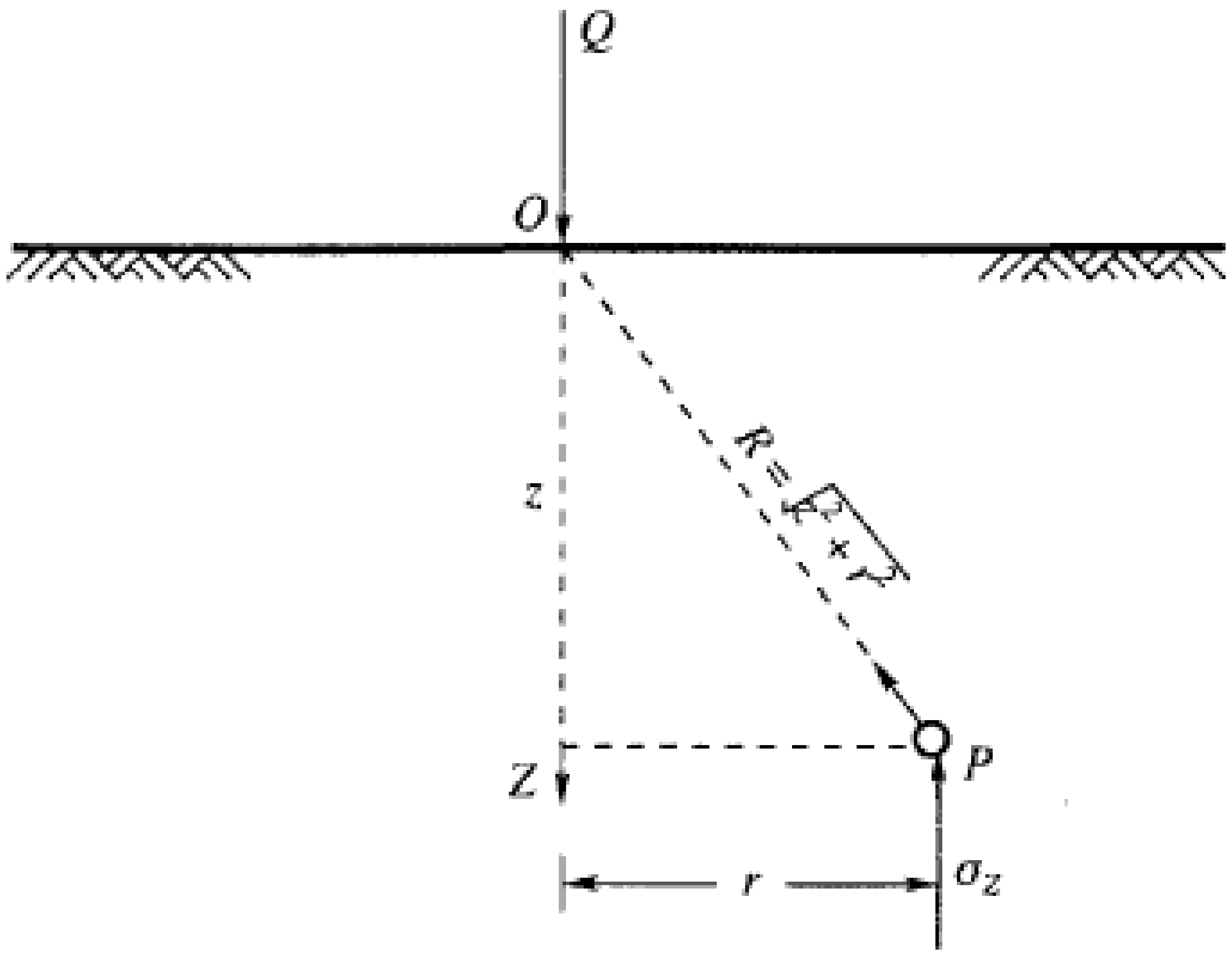
- ✓ Strip surcharges
- ✓ Linear loads
- ✓ Railway embankment loads
- ✓ 3D loads (buildings, footings, 3D surface loads

Loads on the wall:

- ✓ Strip surcharges
- ✓ Linear loads
- ✓ External moments
- ✓ Prescribed displacements

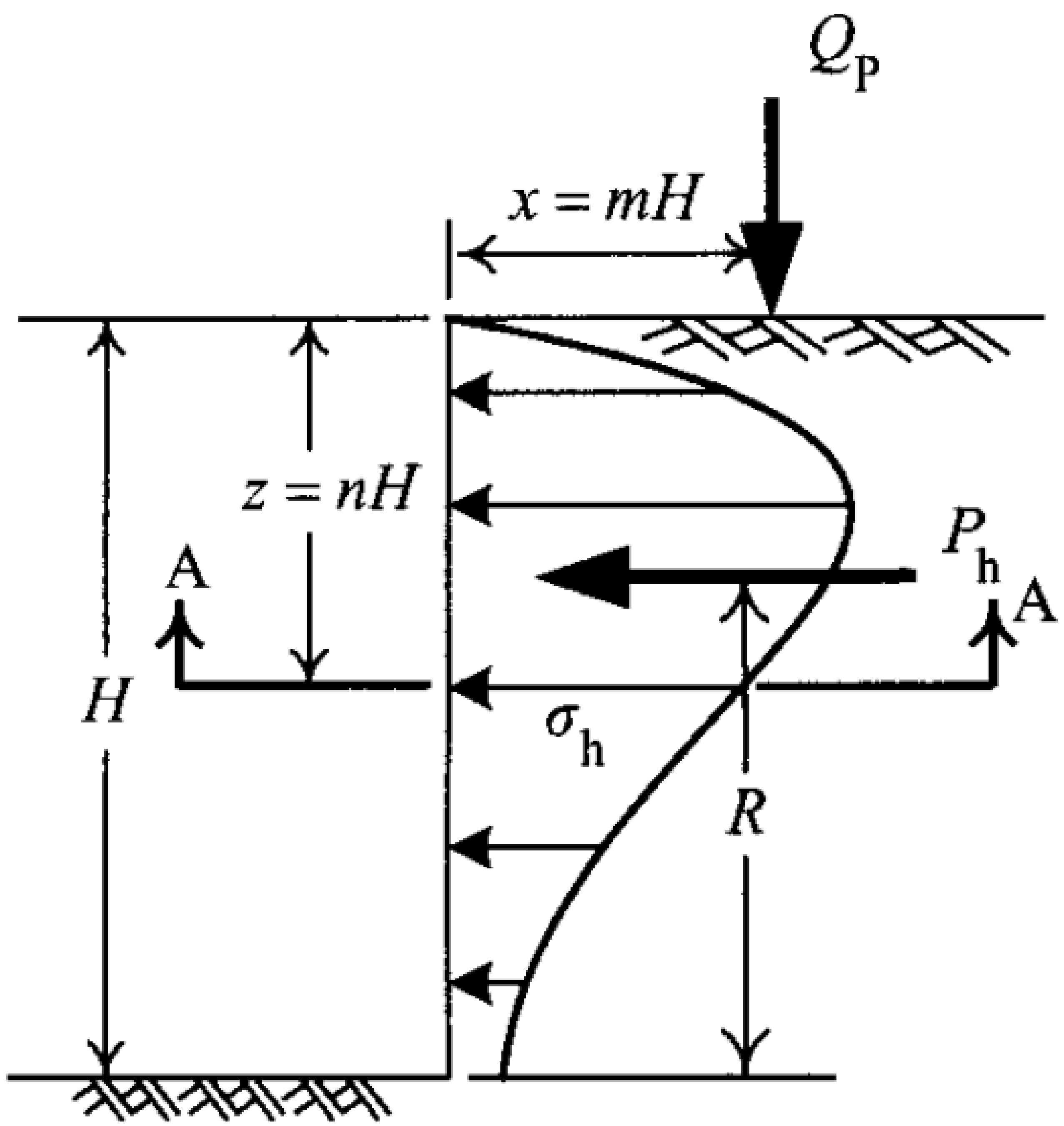
Boussinesq's Equation:

- Point load on the surface of a semi-infinite homogeneous soil mass.
- Wall presence is neglected
- Pressure loads are considered through integration of multiple point loads



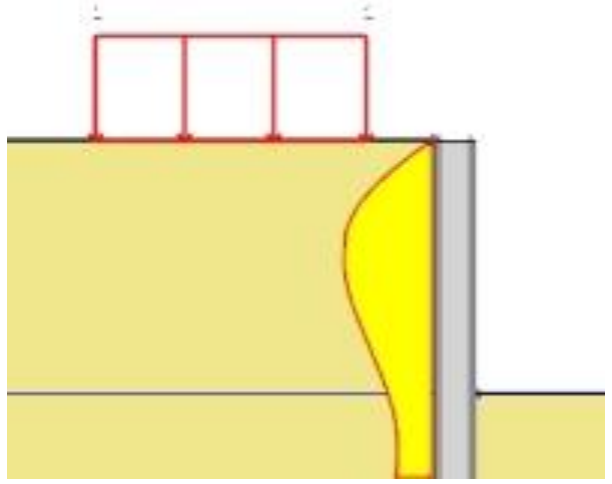
Terzaghi modification of Boussinesq's Equation:

- Modified Boussinesq's equation based on experiments on rigid walls.
- Rigid wall presence is considered

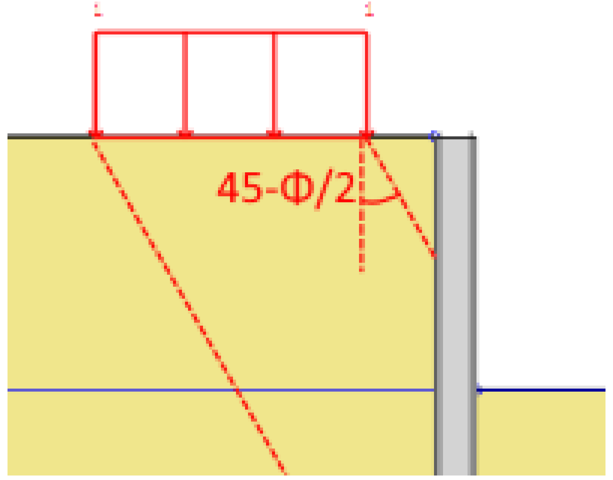


External Loads: Types & Pressure Methods

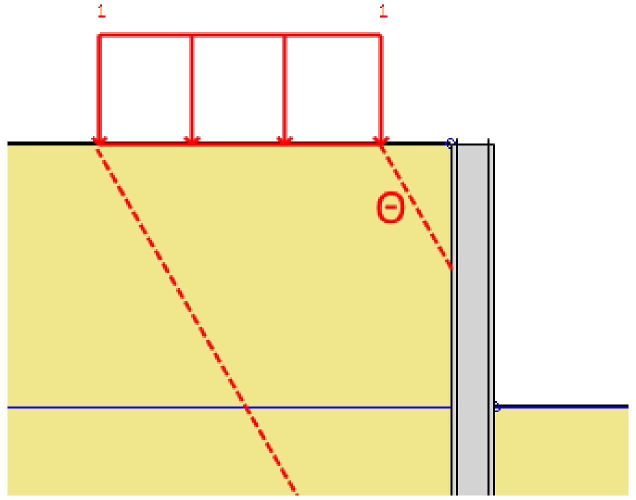
Elasticity



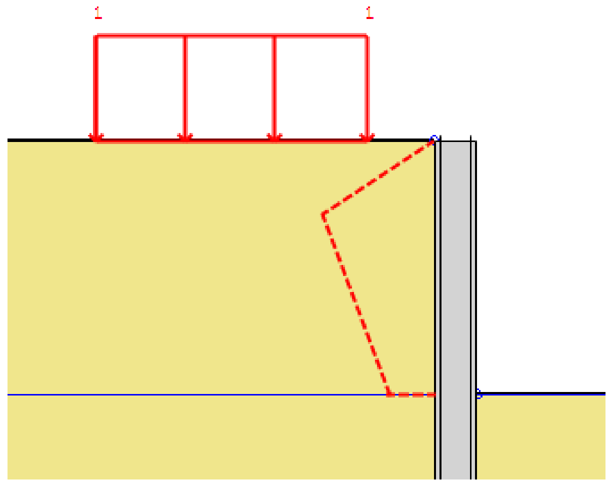
1-Way Distribution



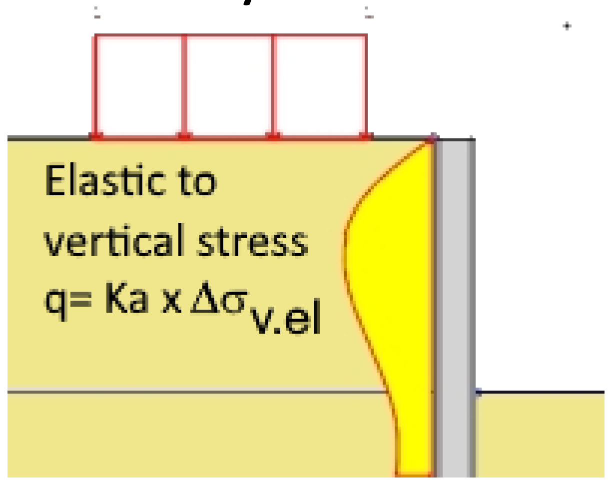
1-Way Distribution



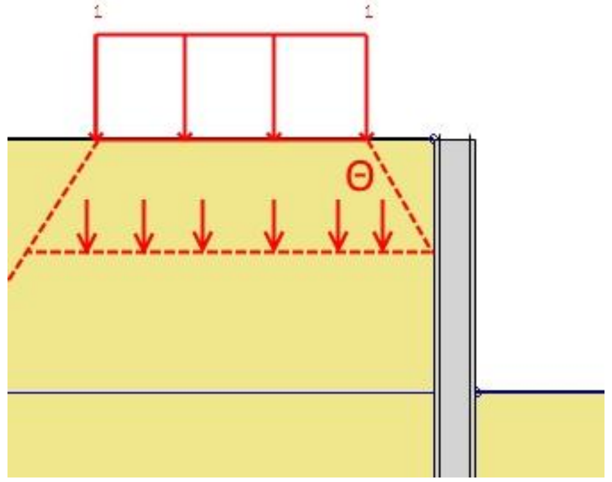
WMATA PLATE A-6B



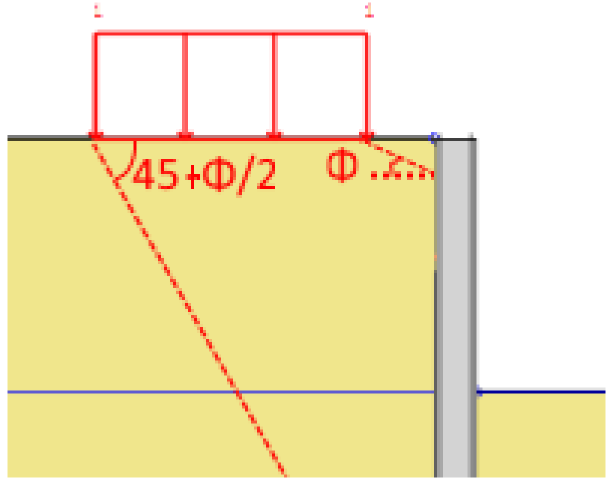
Elasticity σv



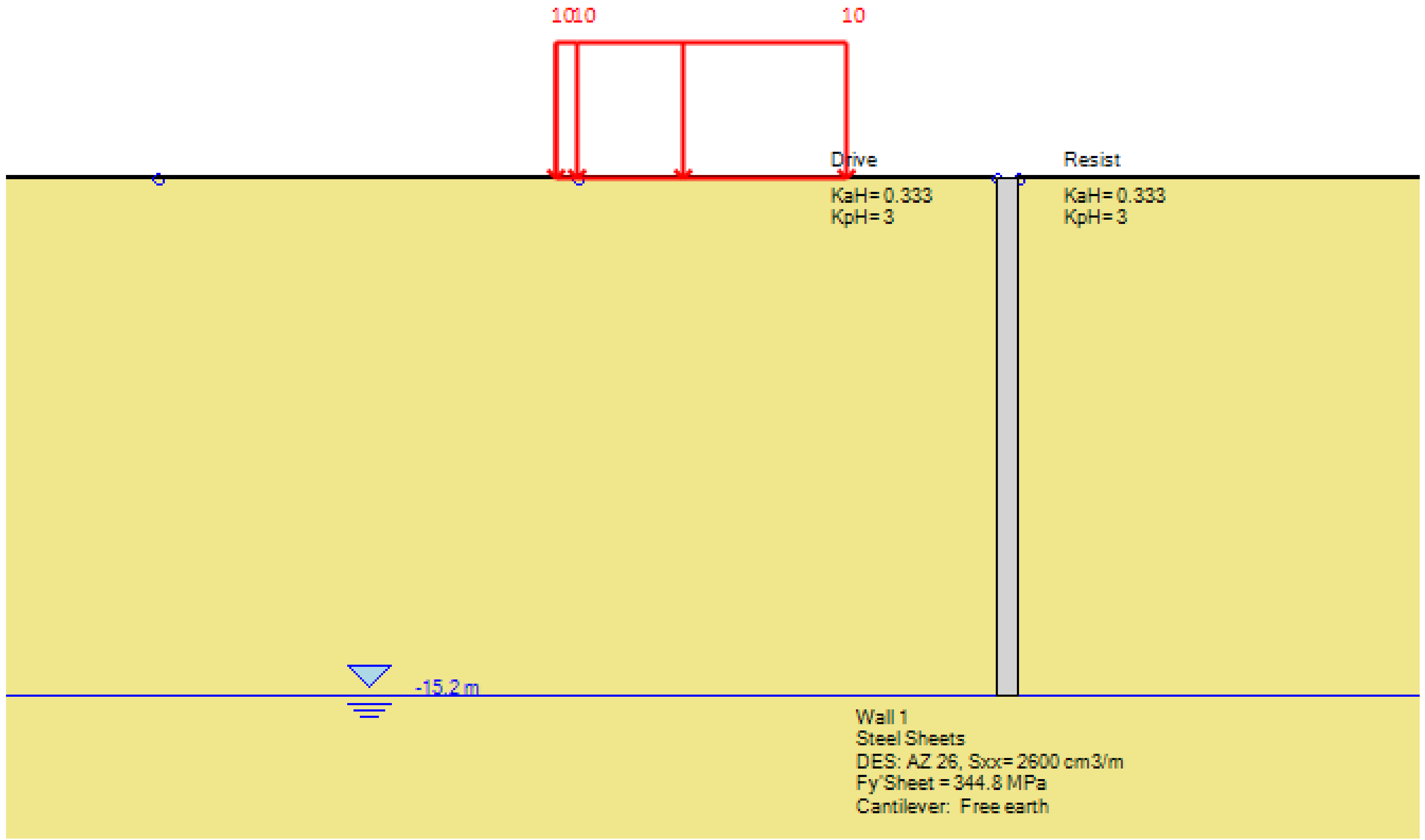
2-Way Distribution



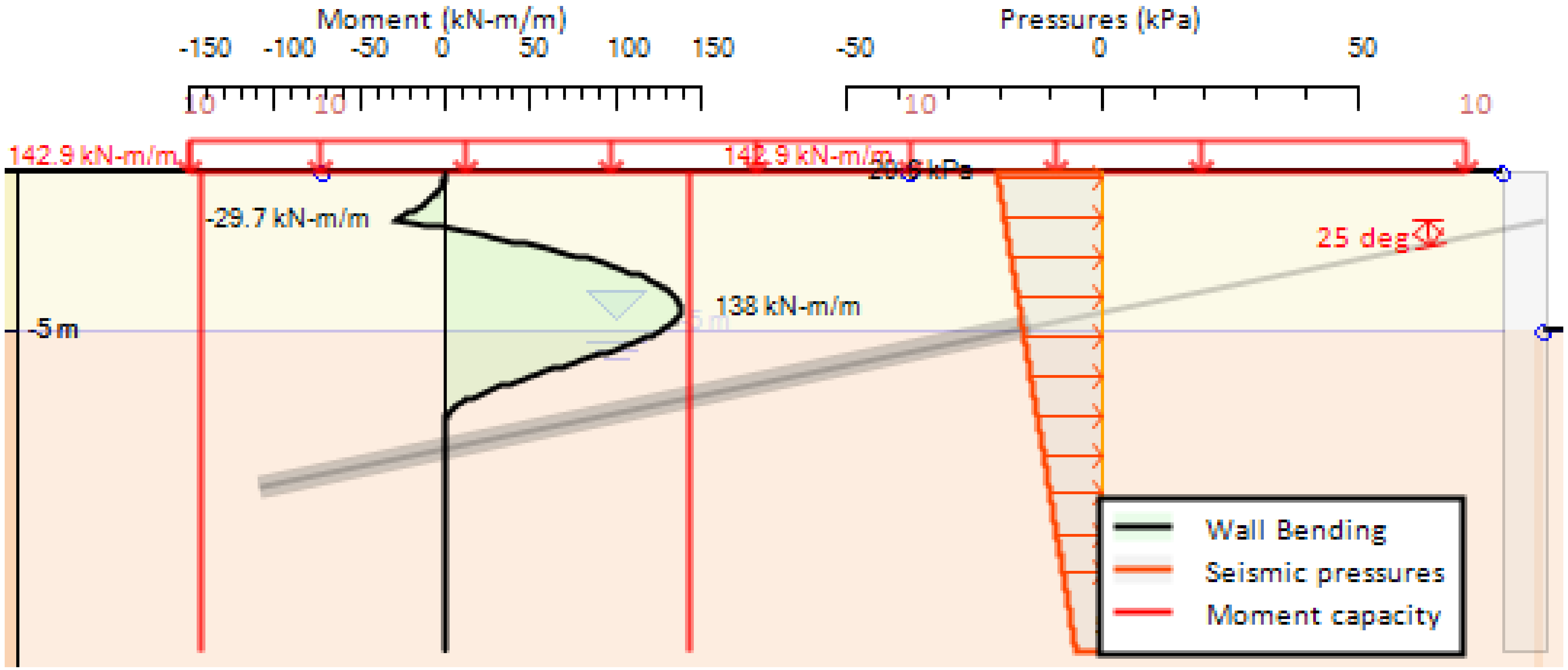
CIRIA Approach



Example 6:


10
10
10
Drive
KaH= 0.333
KpH= 3
Resist
KaH= 0.333
KpH= 3
-15.2 m
Wall 1
Steel Sheets
DES: AZ 26, Sxx= 2600 cm3/m
Fy Sheet = 344.8 MPa
Cantilever: Free earth

Seismic Pressure Methods

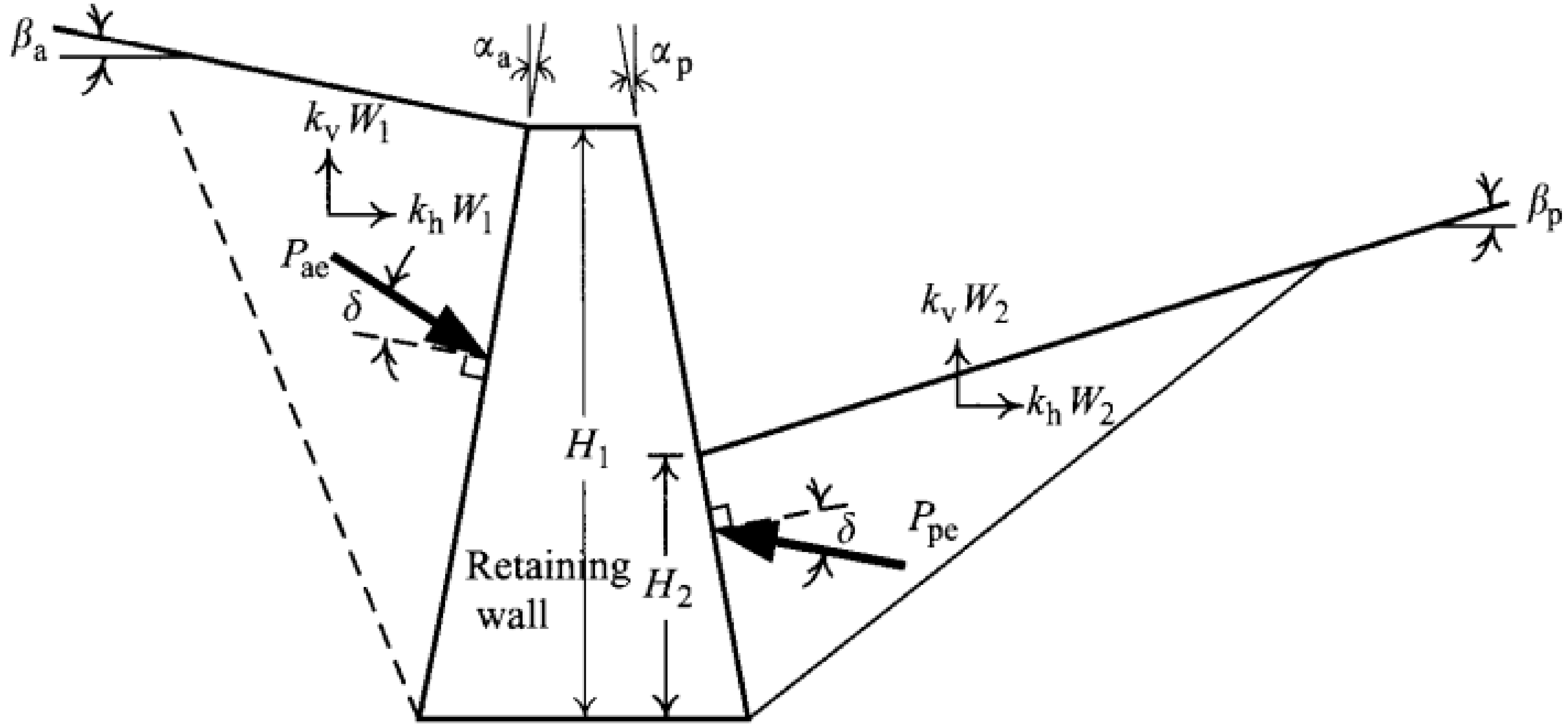


Procedure in DeepEX

- Define Seismic Accelerations Ax and Az
- Select Seismic Pressures Calculation Method
- Select a Seismic Design Standard

Seismic Pressure Methods

Mononobe-Okabe :



W_1: Weight of wedge in the active zone

W_2: Weight of wedge in the passive zone

Other Seismic Pressure Methods

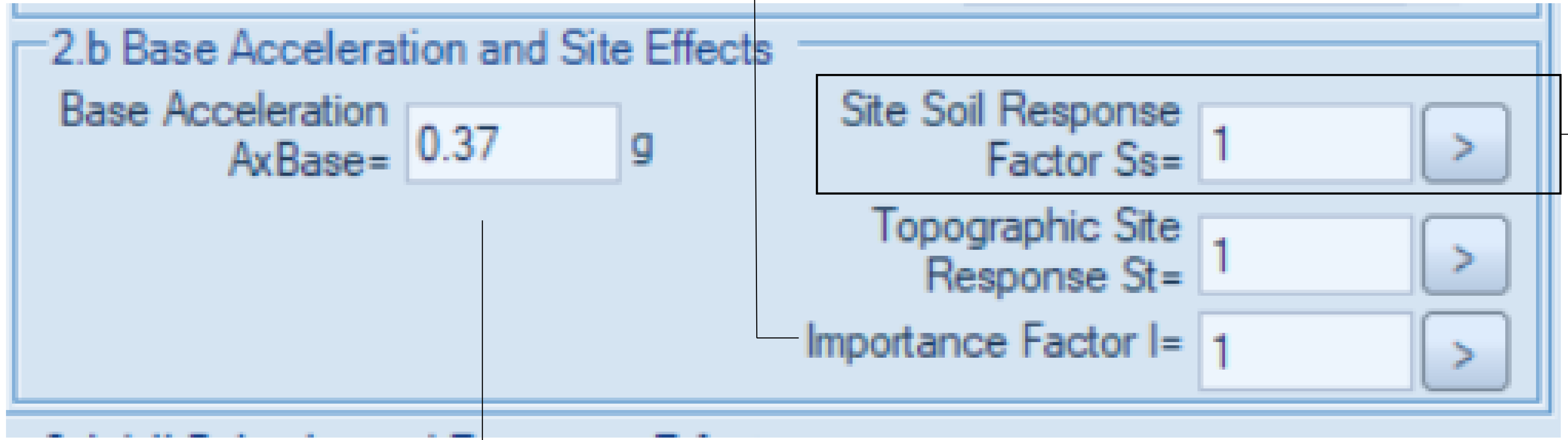
- Semirigid
- Wood Automatic
- Wood Manual

Seismic Pressure Methods

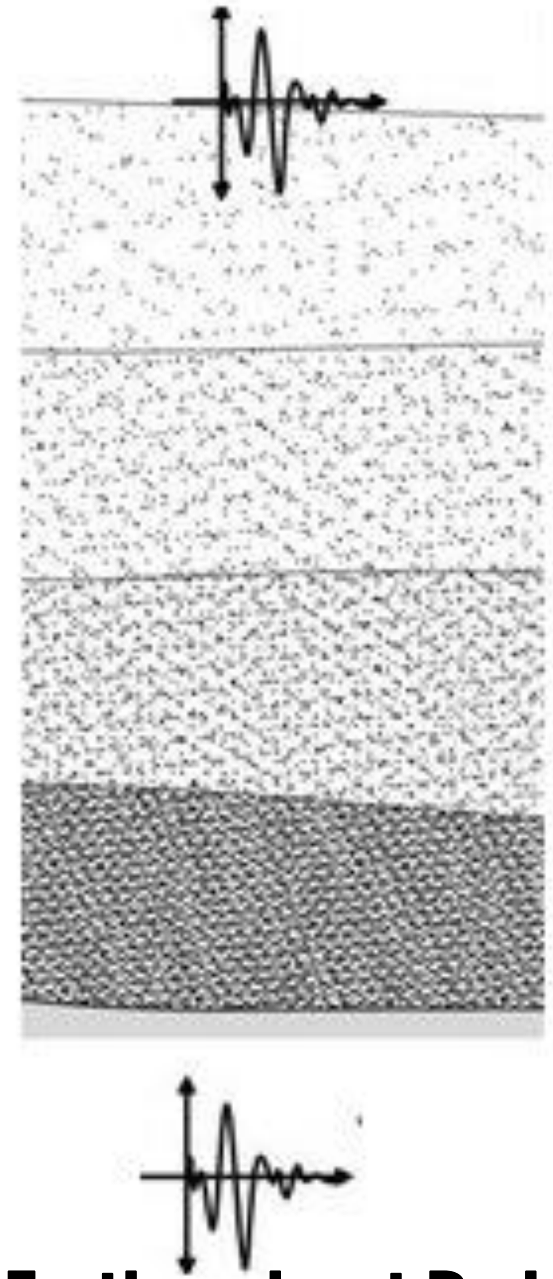
Calculation of design acceleration

- The user can directly prescribe the design acceleratio
- Use bedrock acceleration and factors to generate a_{de}

Seismic code	Occupancy category Higher	Moderate	Lower
IS 1893-Part1	1.5	1.2	1.0
Canadian Building Code Act	1.5	—	1.0
BS EN 1998-1	1.5	—	0.8
ASCE/SEI 7	1.5	1.25	1.0
NZS 1170 Part 5	1.3	—	0.6
NBC 105	2.0	1.5	1.0
EAK 2000	1.3	—	0.85
Iranian Standard 2800	1.2/1.4	1.0	0.8



Free-field motion



Earthquake at Bedrock

$$k_h = \left(\frac{a_g}{g}\right) S \frac{1}{r}$$

Seismic Pressure Methods

Calculation of Response R factor

- Rigid walls experience greater forces compared to yielding walls

$$k_h = \left(\frac{a_g}{g}\right) S \frac{1}{r}$$

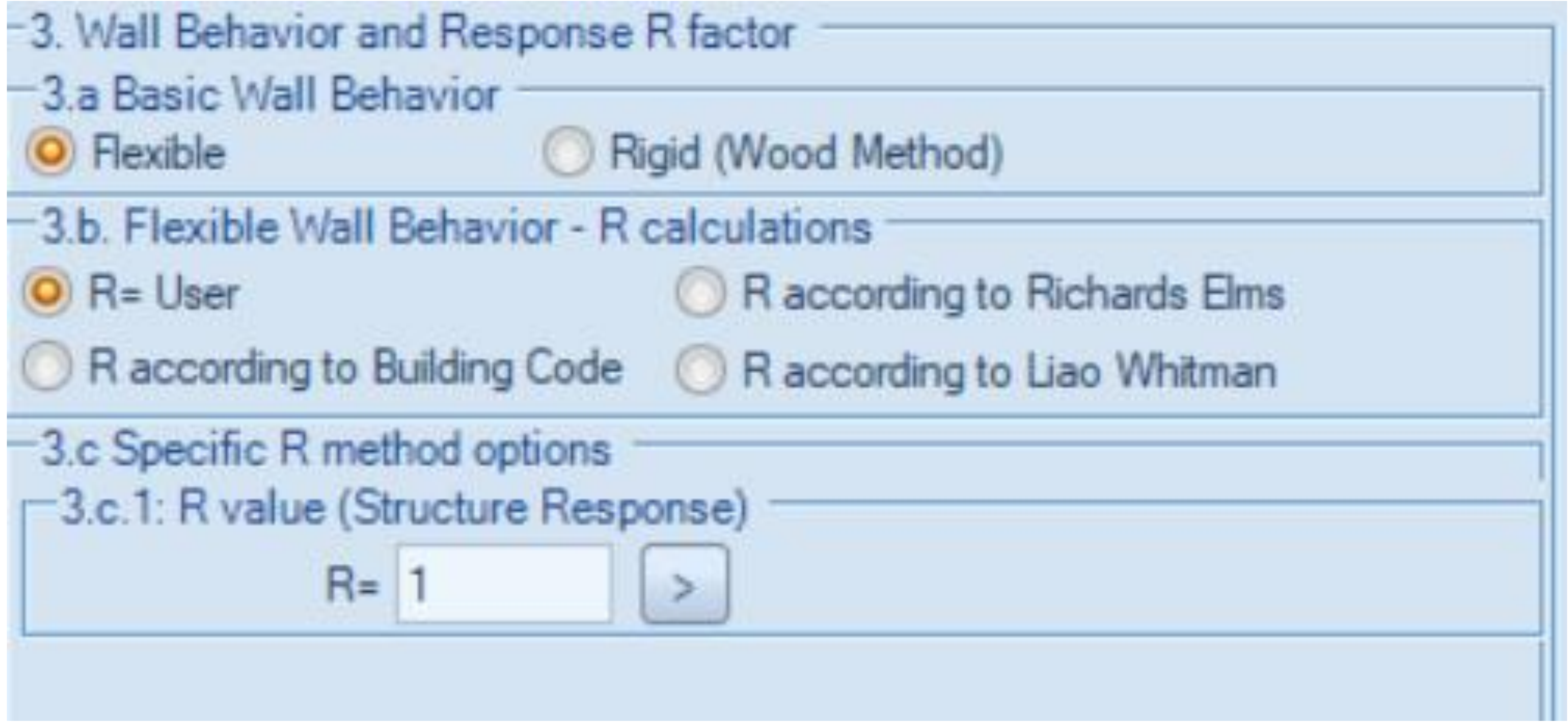


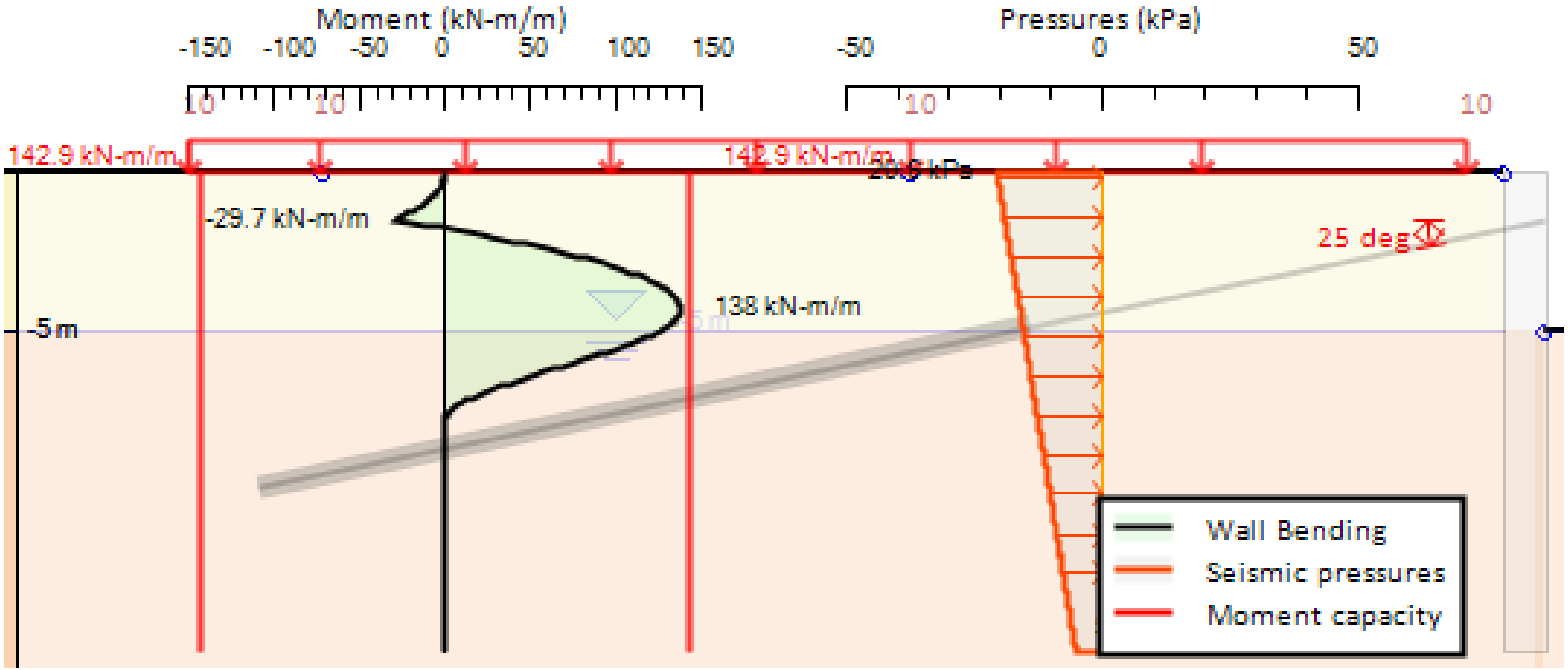
Table 7.1 — Values of factor *r* for the calculation of the horizontal seismic coefficient

Type of retaining structure	r
Free gravity walls that can accept a displacement up to $d_r = 300\ \alpha \cdot S$ (mm)	2
Free gravity walls that can accept a displacement up to $d_r = 200\ \alpha \cdot S$ (mm)	1,5
Flexural reinforced concrete walls, anchored or braced walls, reinforced concrete walls founded on vertical piles, restrained basement walls and bridge abutments	1

Eurocode EC8

Soil Pressure Methods (LEM Analysis)

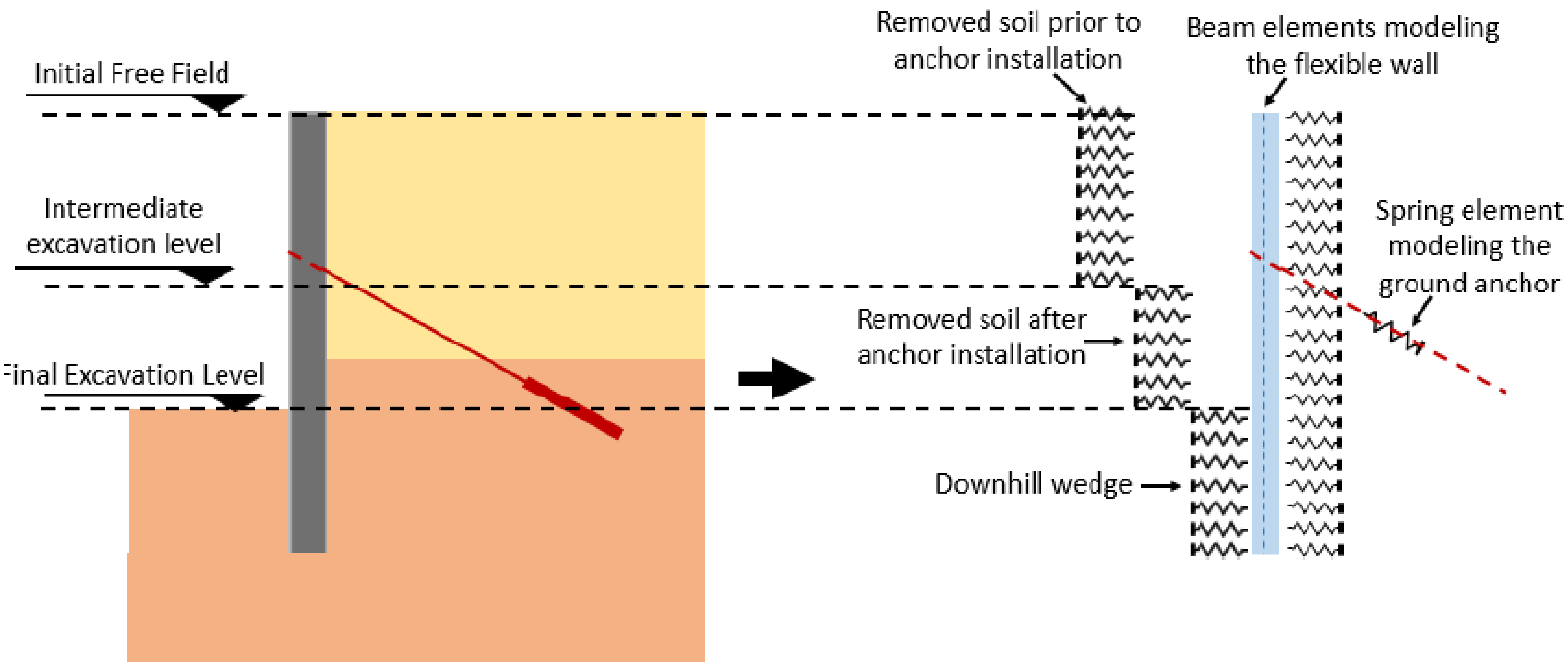
Example 7:



NON LINEAR ANALYSIS

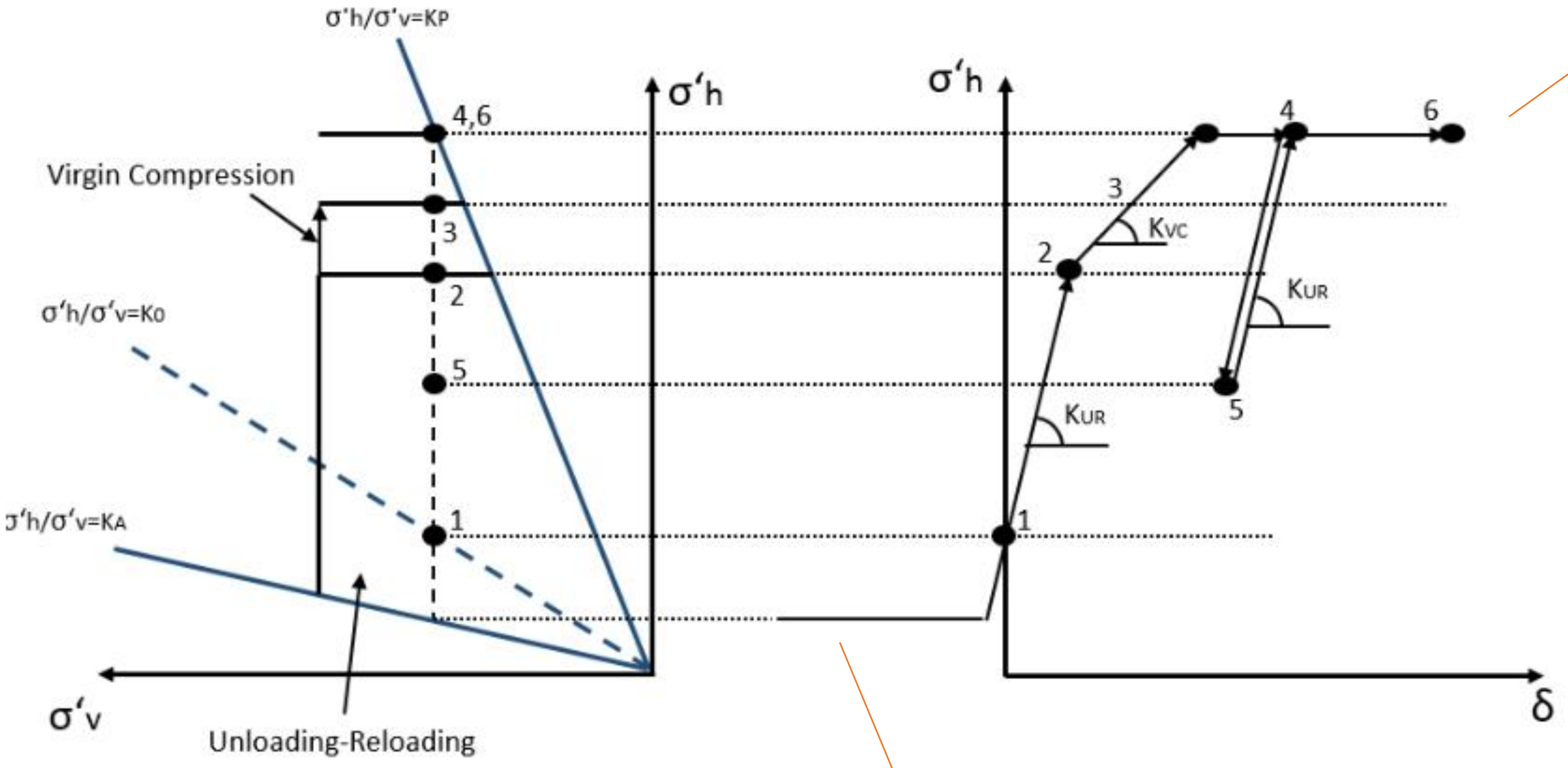
- Fundamentals
- Setting up elasticity properties
- Limitations

Non-linear winkler analysis



Non-linear winkler analysis

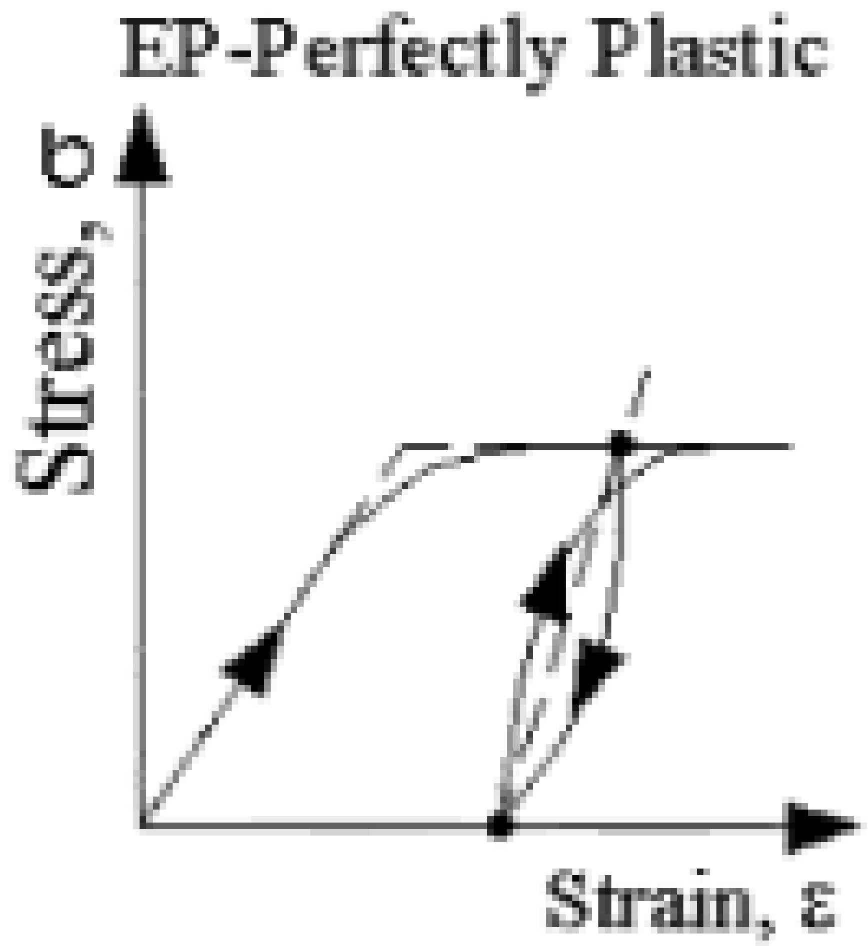
$$\sigma'_h = K_P \cdot \sigma'_v + 2 \cdot c' \cdot \sqrt{K_P}$$



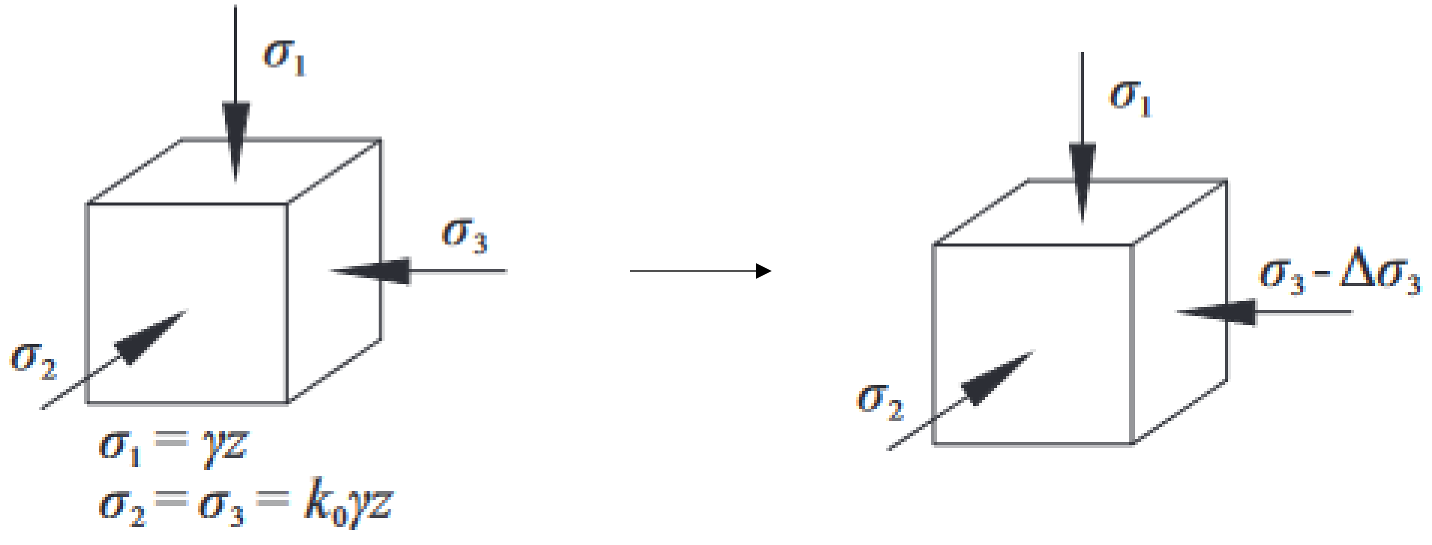
$$\sigma'_h = K_A \cdot \sigma'_v - 2 \cdot c' \cdot \sqrt{K_A}$$

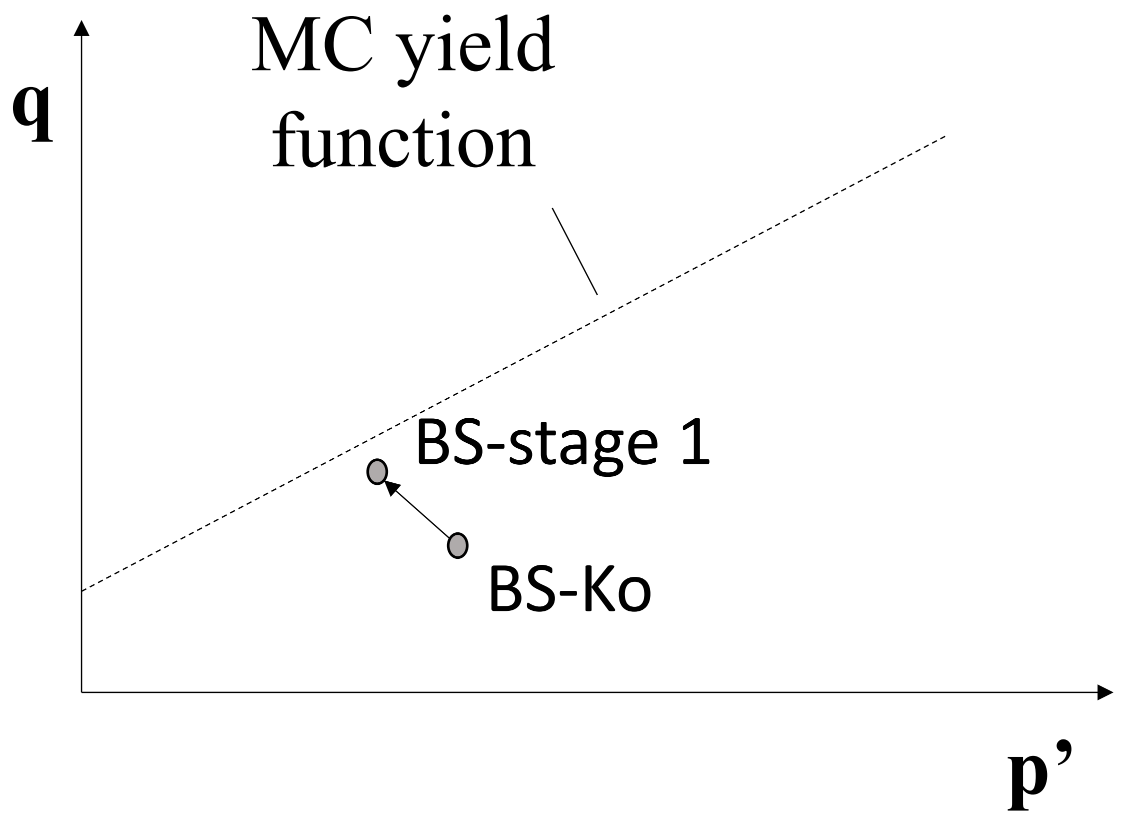
Linear Perfectly plastic Model

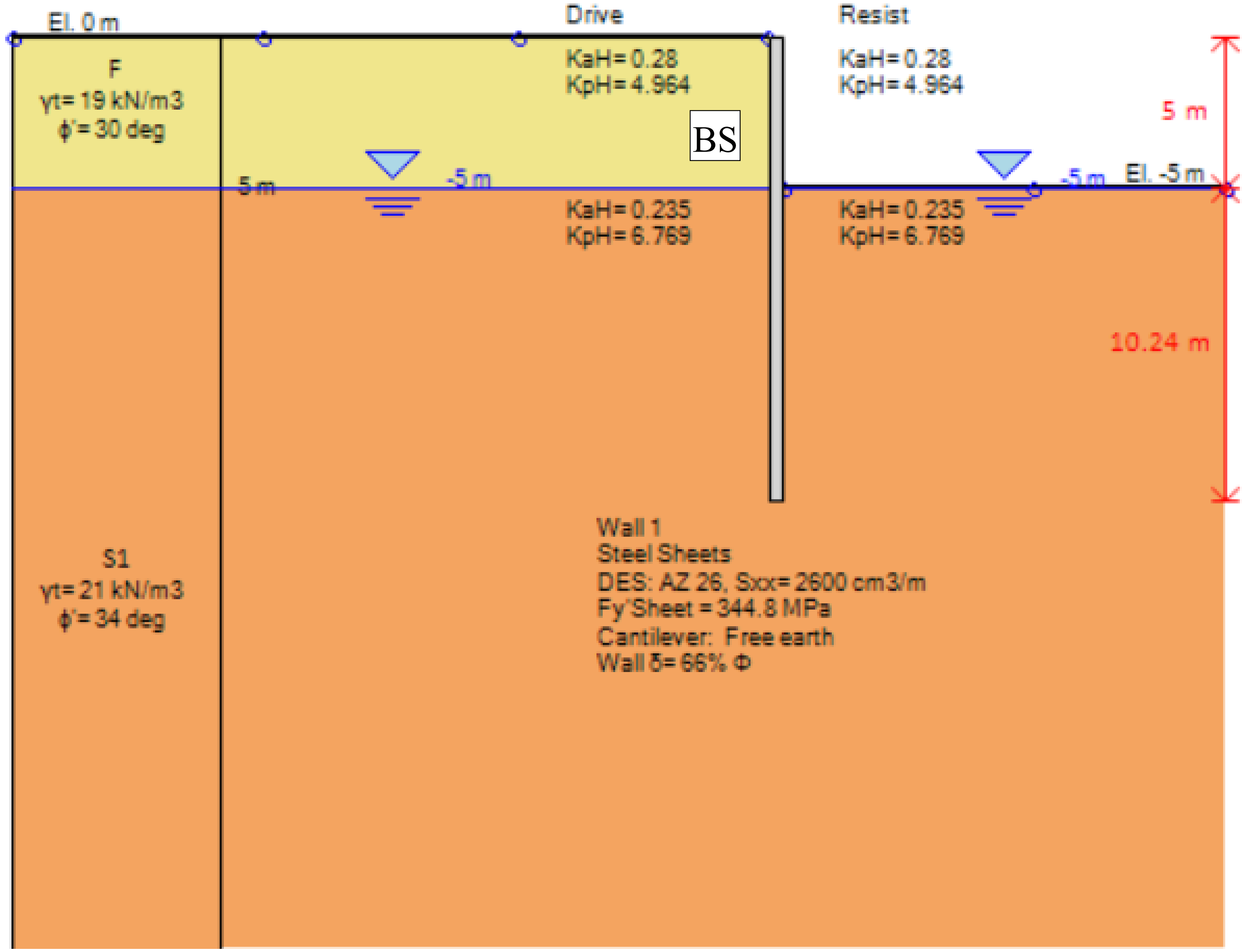
- Elastic behavior prior to yielding
- Detailed unloading reloading behavior



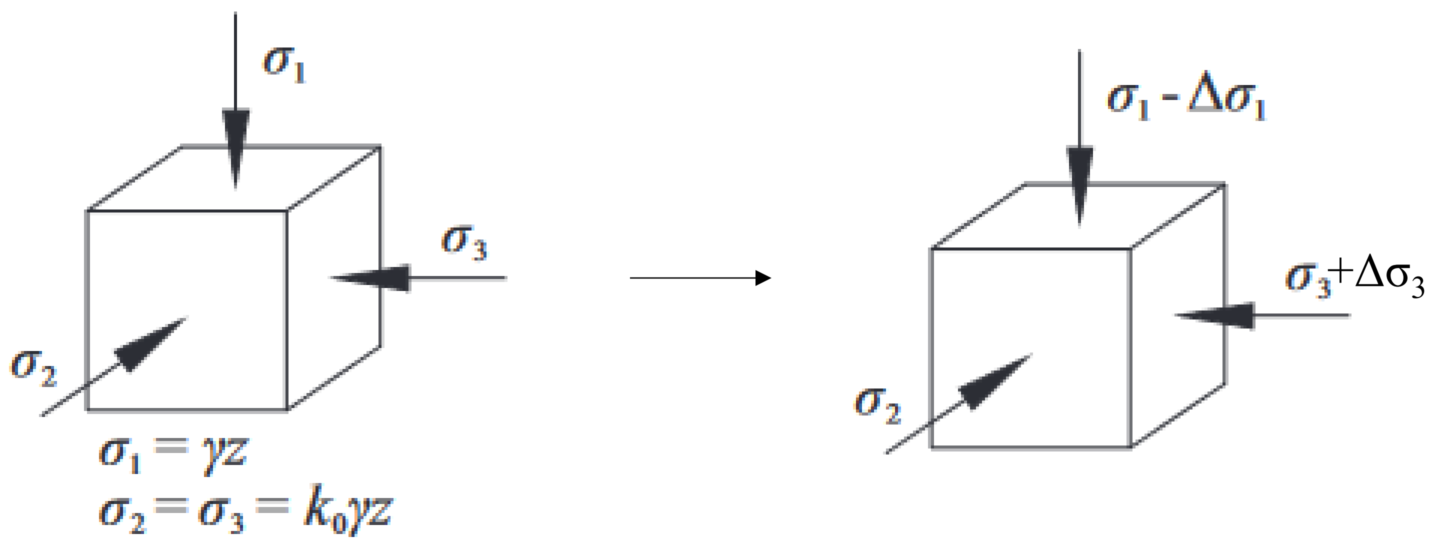
Non-linear winkler analysis

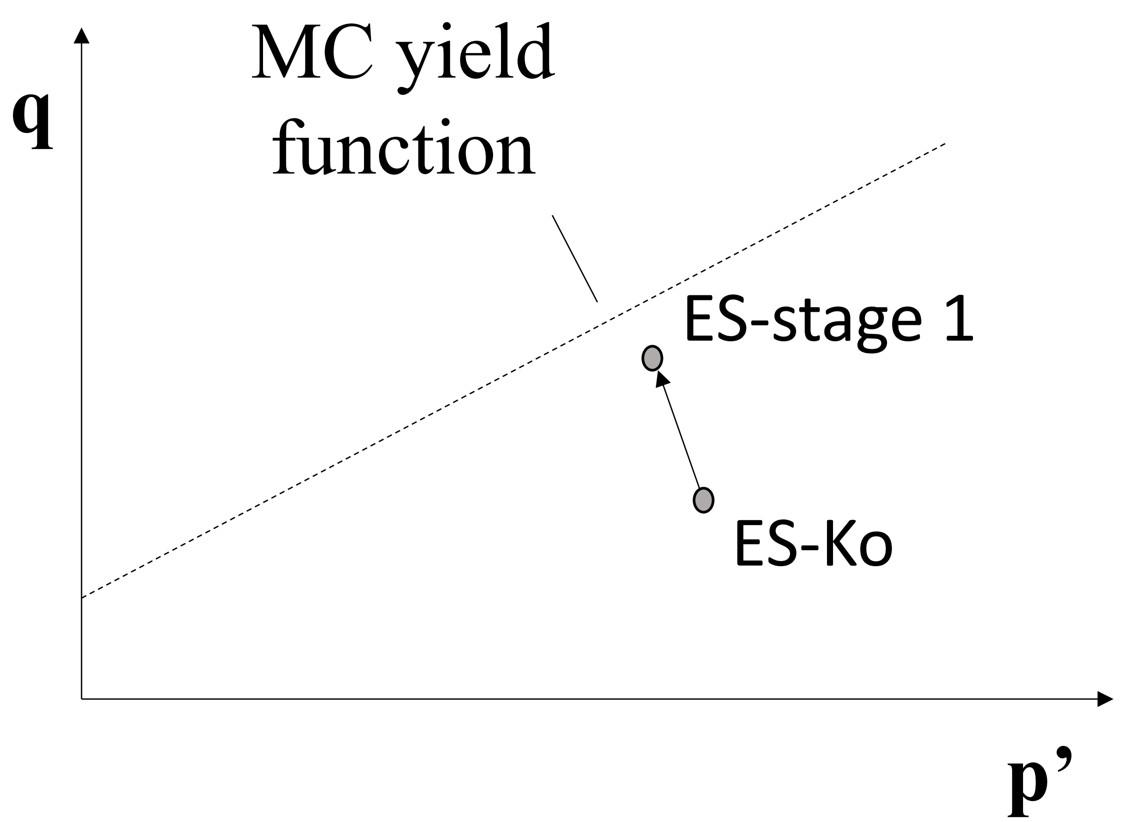


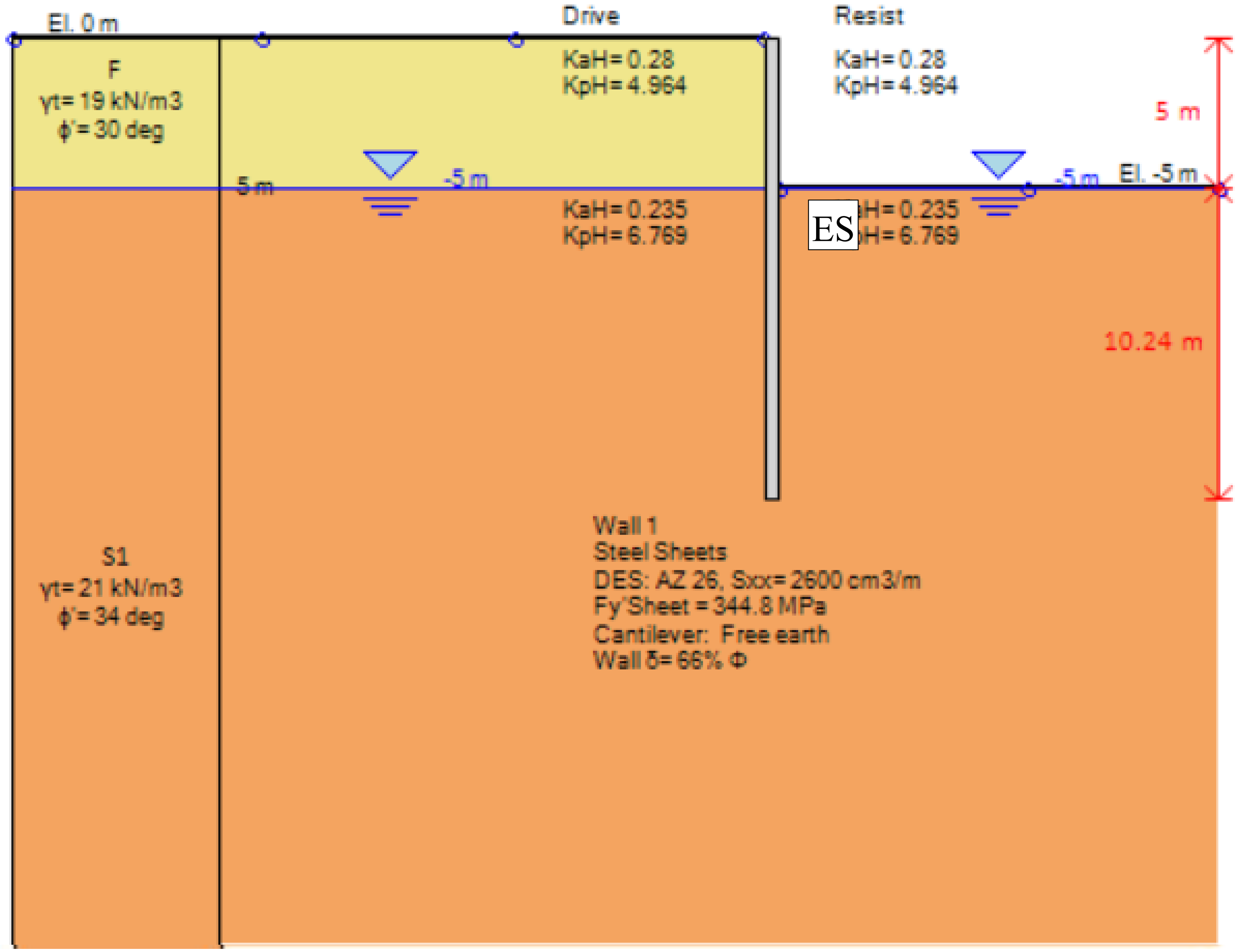




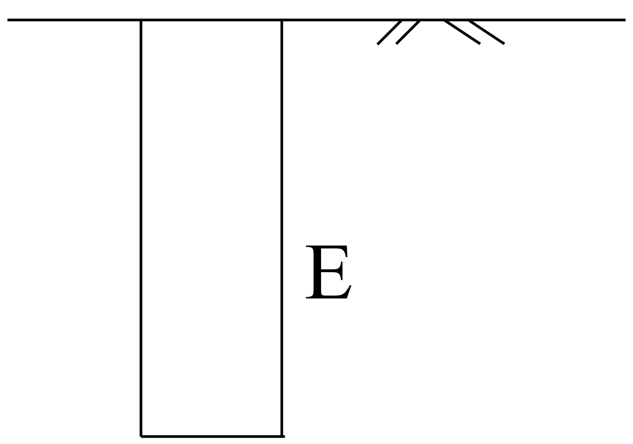
Non-linear winkler analysis



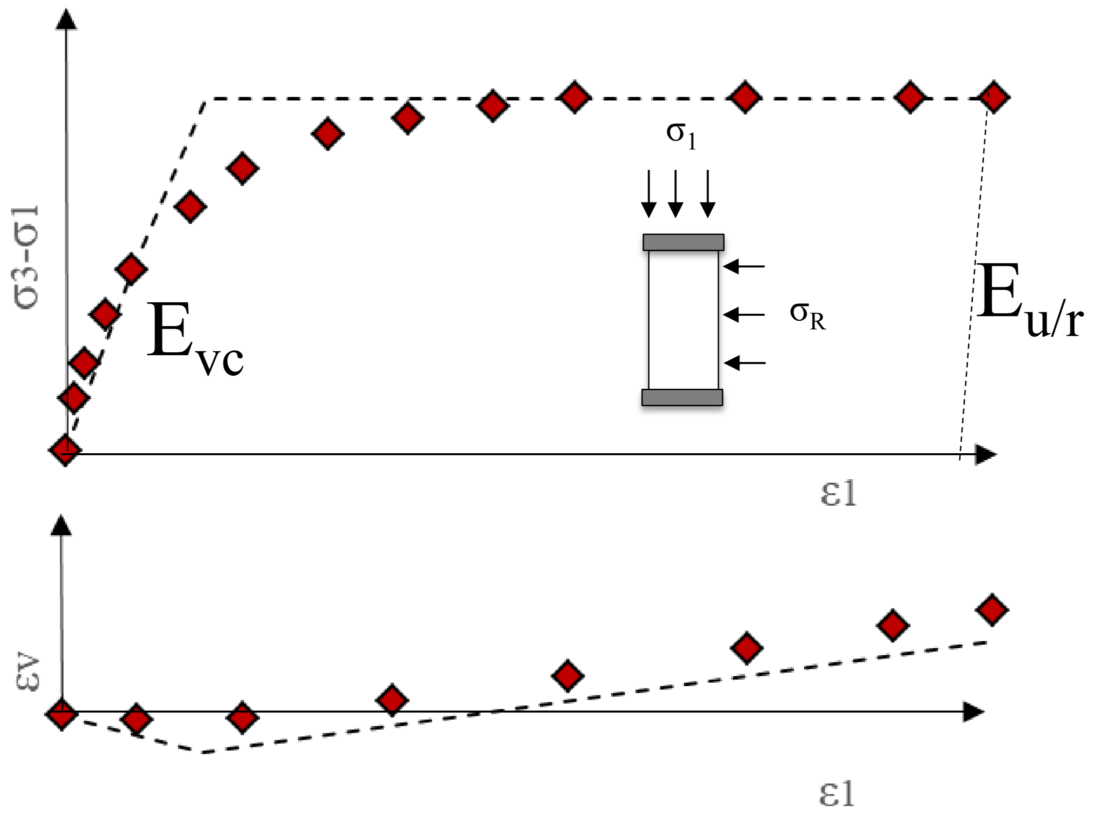




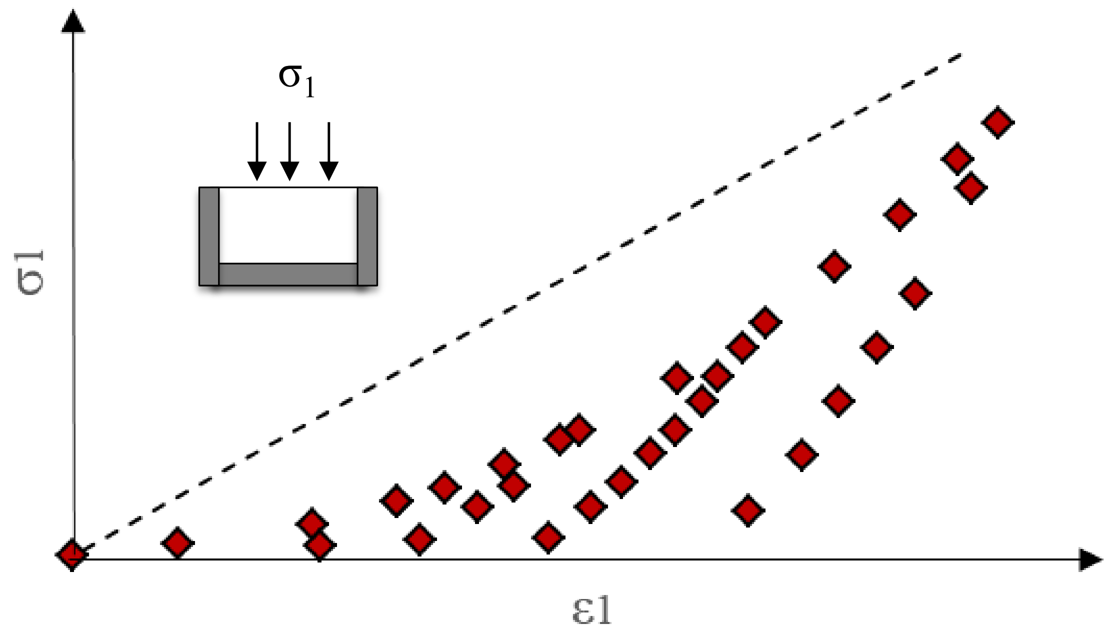
Non-linear winkler analysis



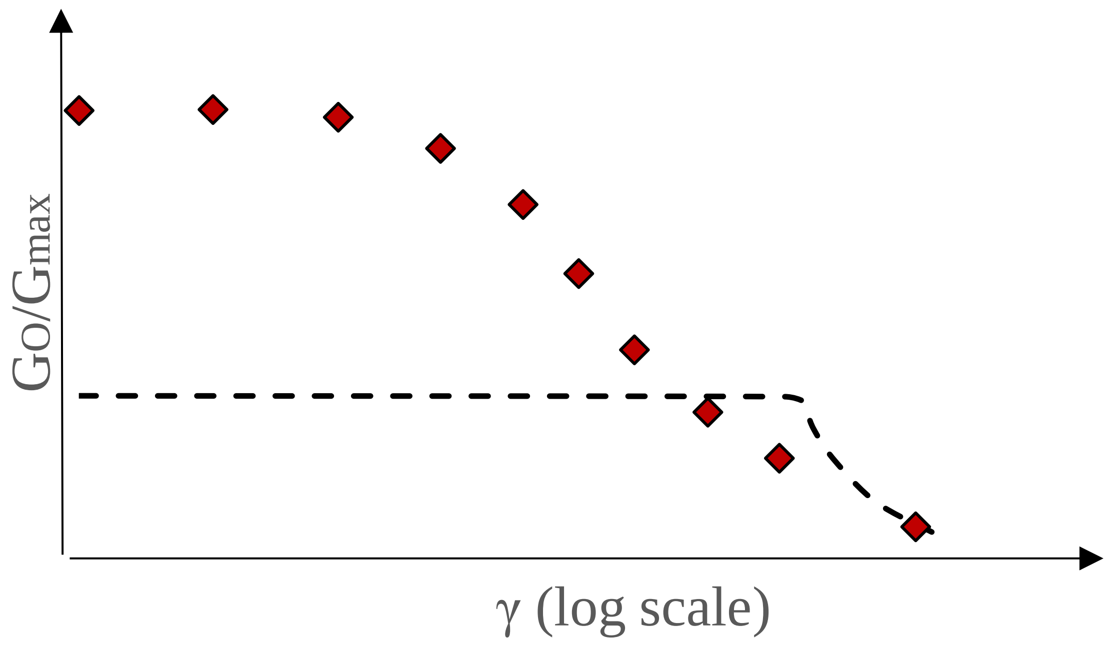
(a) Stress dependent elastic properties



(b) Triaxial test results



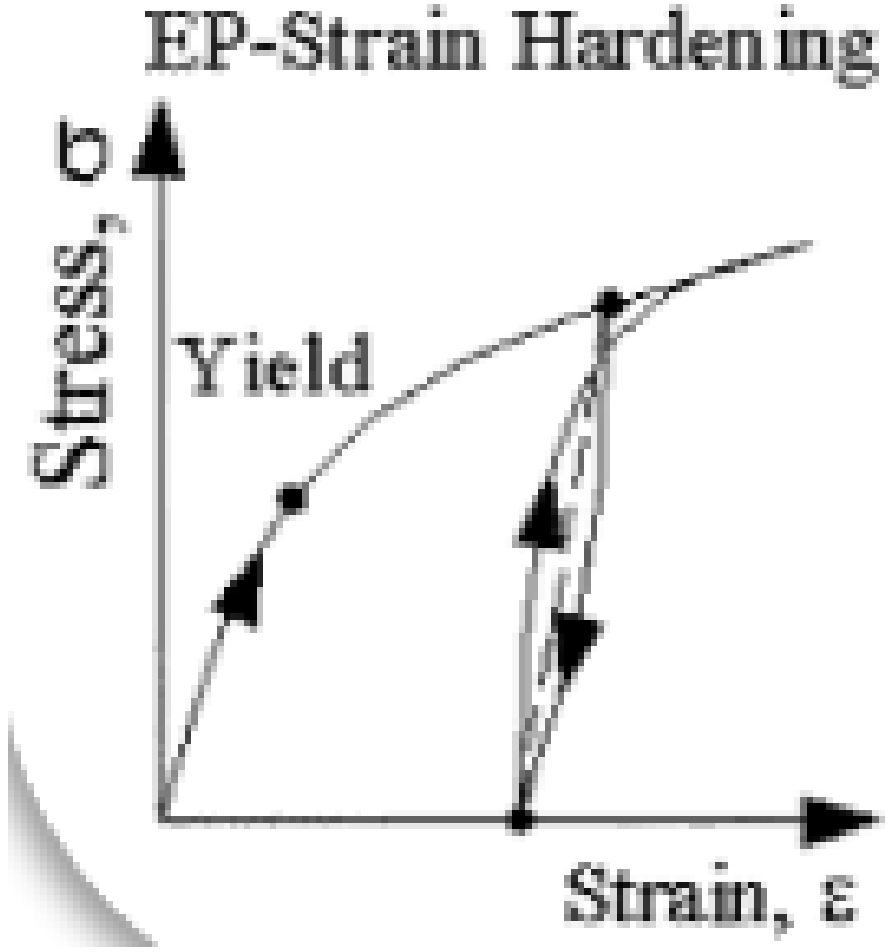
(c) Oedometer test results



(d) Small strain Stiffness

Hyperbolic elastoplastic Model

- Inelastic behavior prior to yielding
- Pressure dependent nonlinear stiffness
- Detailed unloading reloading behavior



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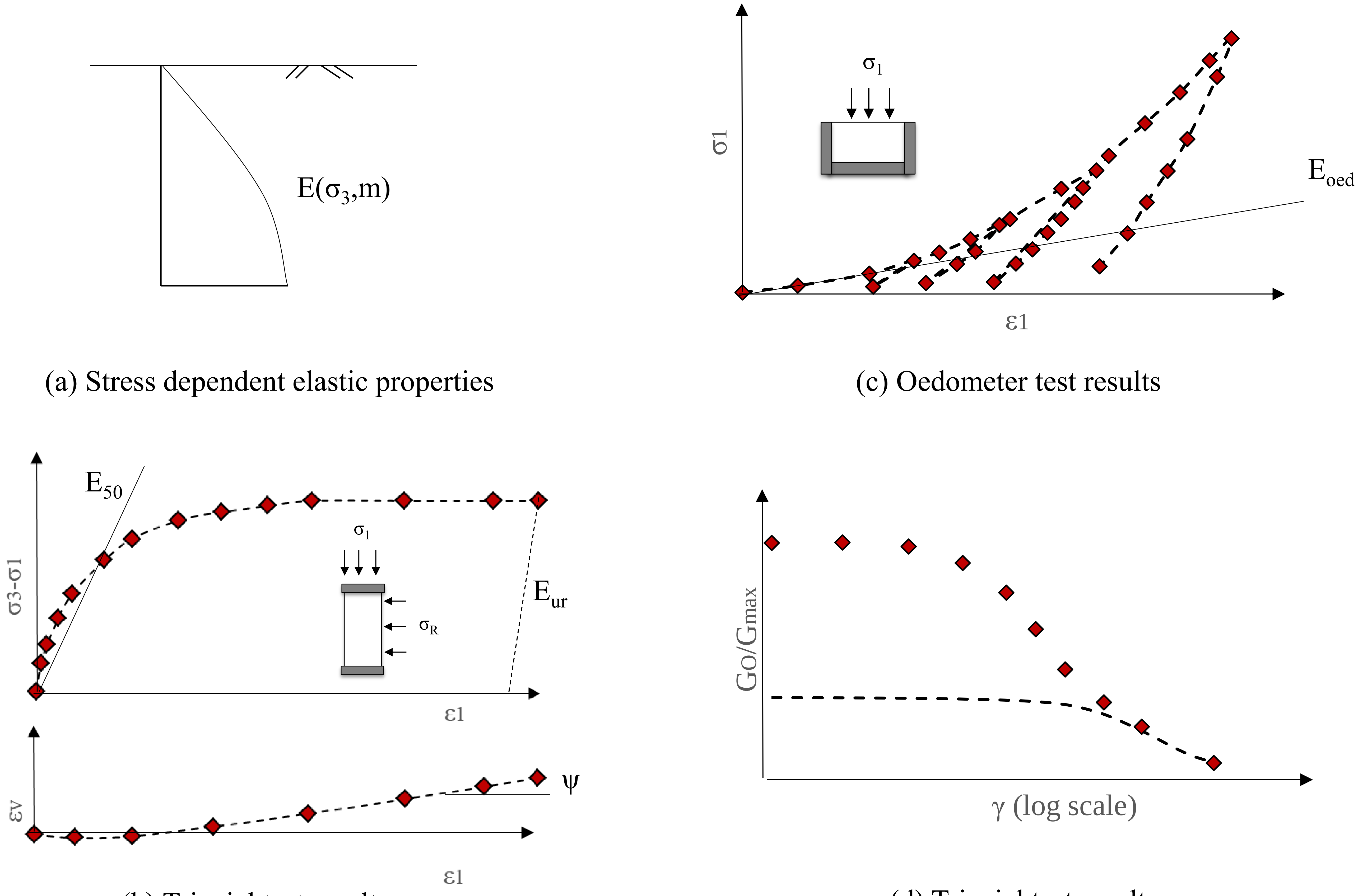
Non-linear winkler analysis



(a) Stress dependent elastic properties

(c) Oedometer test results

(b) Triaxial test results

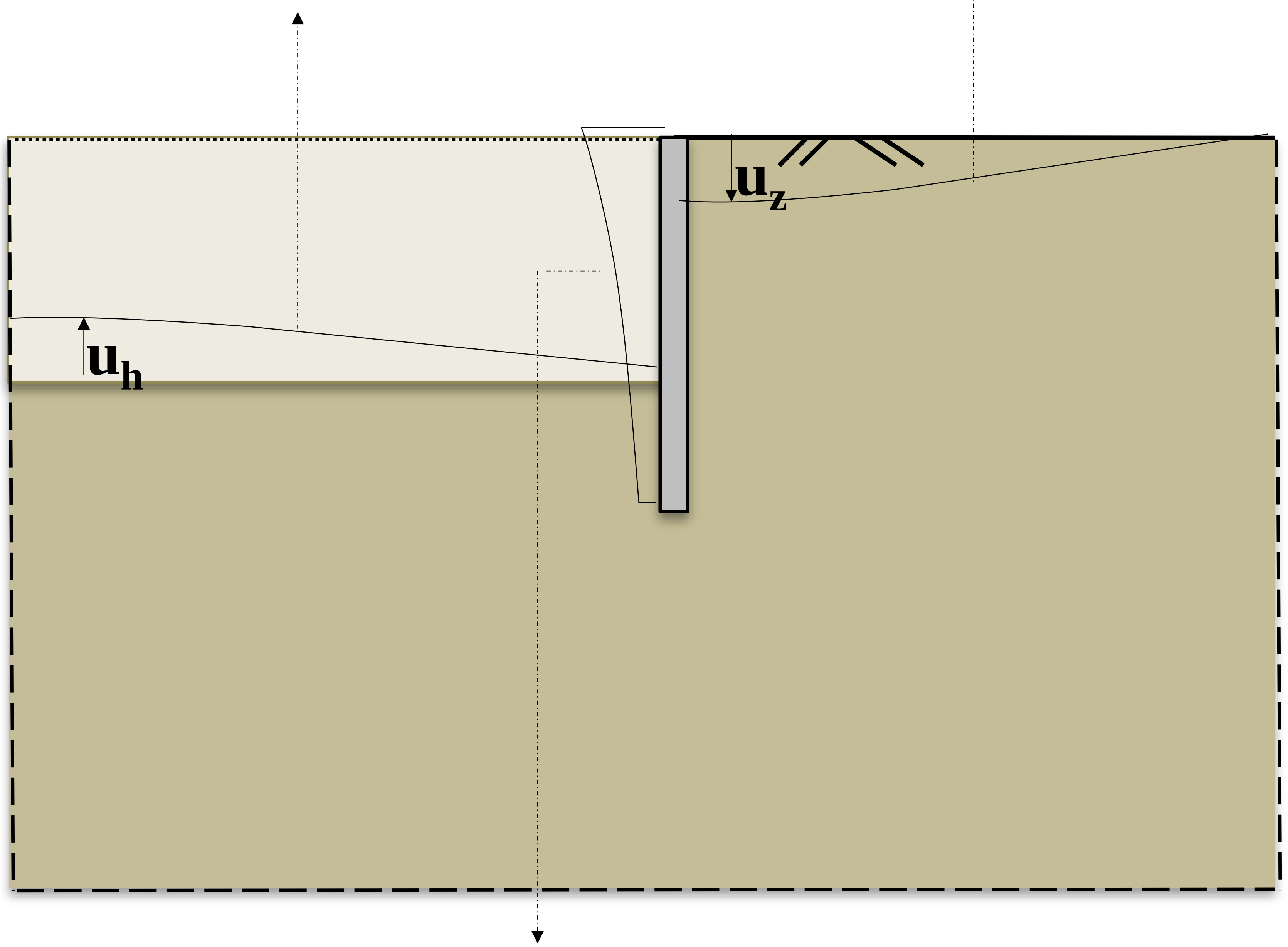
(d) Triaxial test results

Non-linear winkler analysis

Dominating properties in excavations:

unrealistic bottom heave **[unloading/reloading stiffness]**

Unrealistic surface settlement [**pre yielding stiffness]**

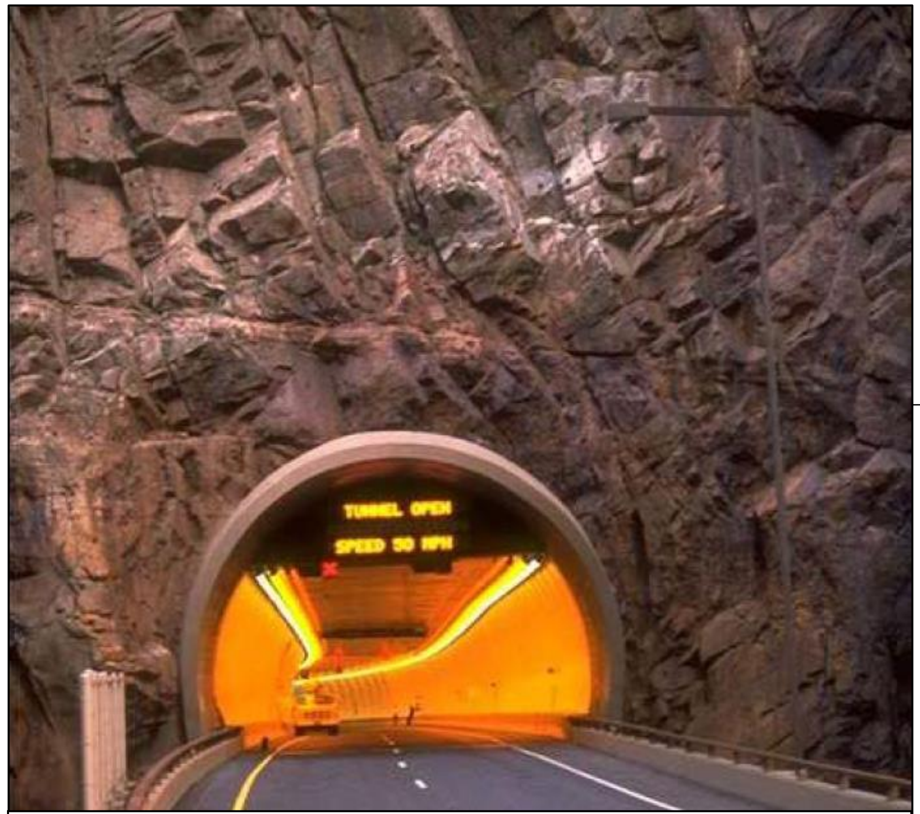


Unrealistic wall displacement without [**small strain stiffness and stress dependency]**

Subgrade Model

- Elastic behavior
- Defined by a $K_{subgrade}$ modulus
- mainly use for calibration with elastic assumption

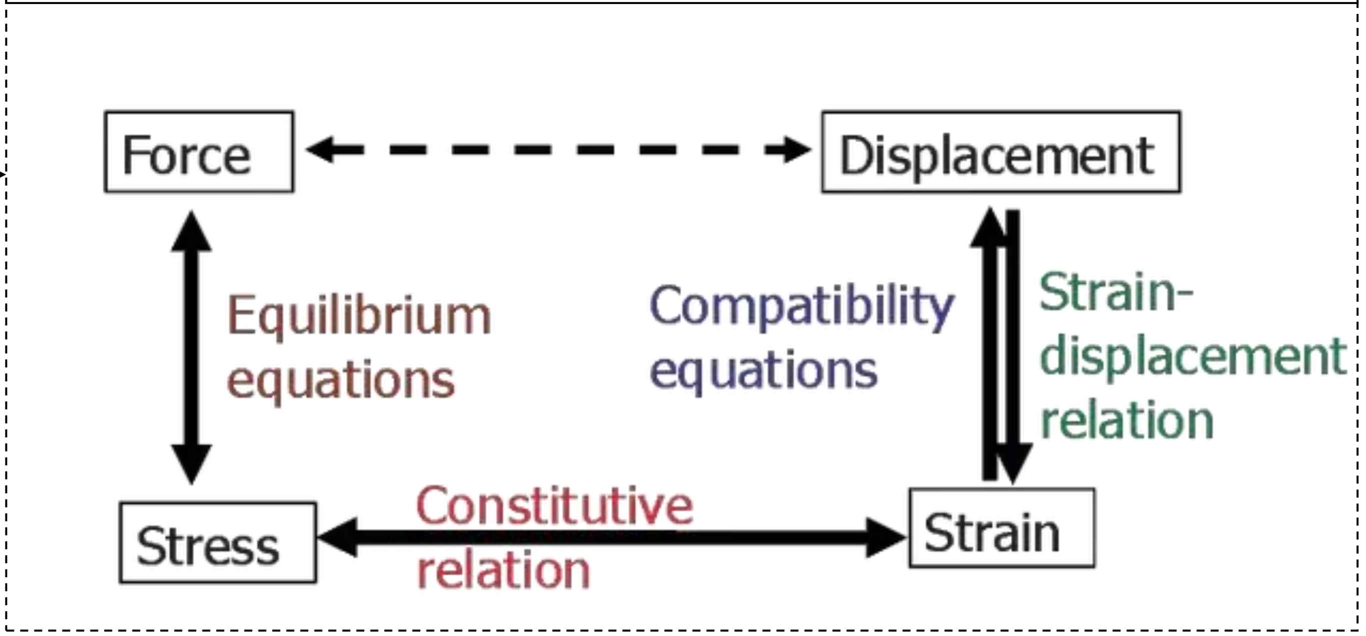
Finite element method (FEM)



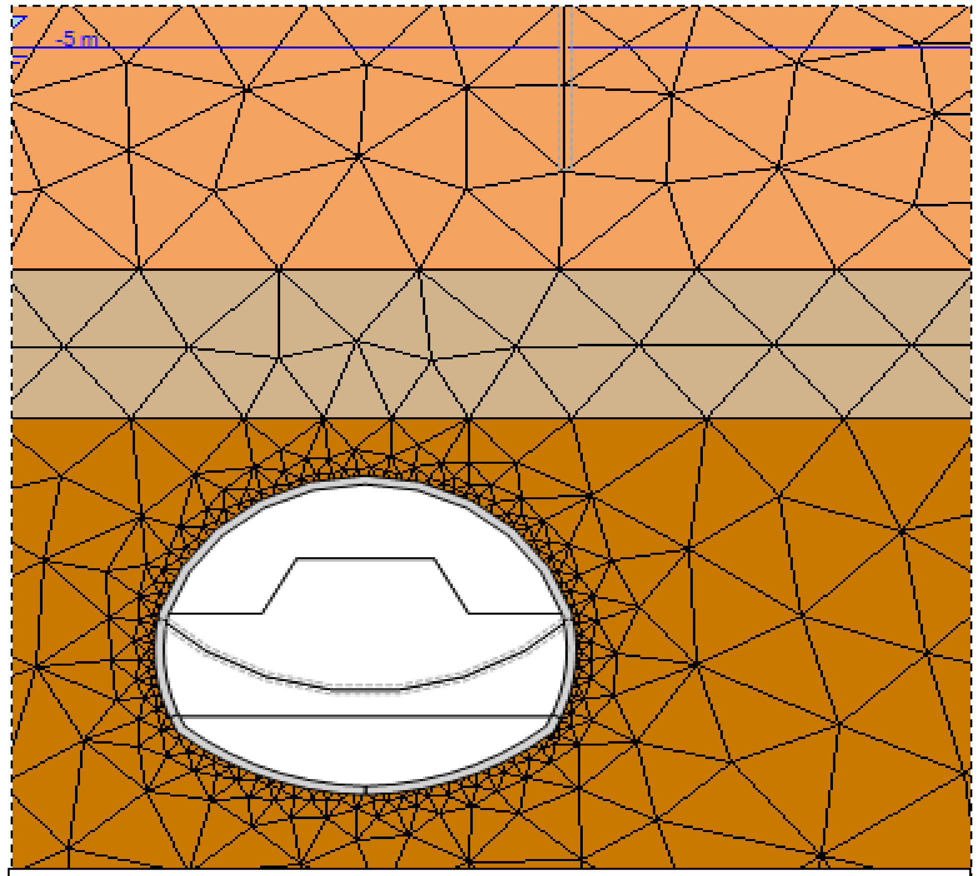
Physical structure

Modelling assumptions

Mathematical formulation



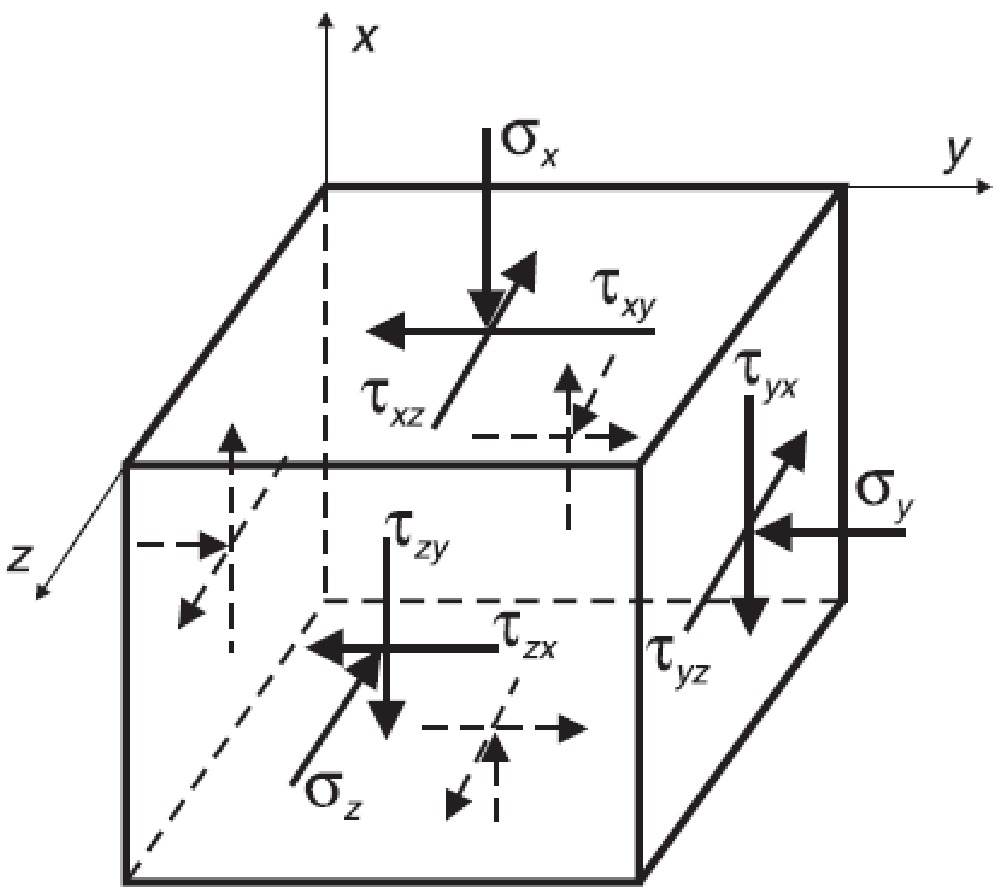
Discretization



FEM numerical model

(a) Equilibrium equations

Stresses within the soil medium must satisfy equilibrium



Mathematical form: Cauchy momentum equation

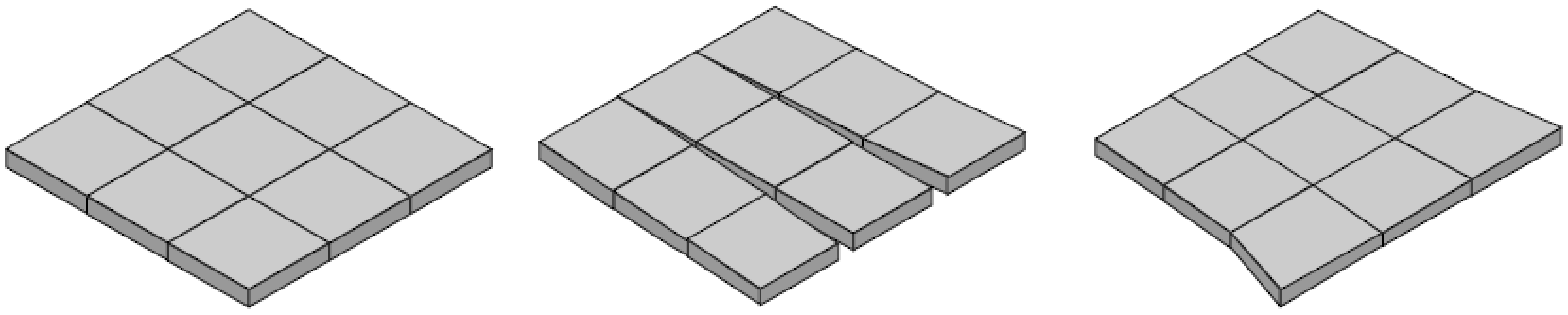
External body forces

$$div_{\mathbf{x}}\boldsymbol{\sigma} + \boldsymbol{b} = \rho\ddot{\boldsymbol{u}}$$

Divergence of stress tensor

Acceleration (equal to zero for static analysis)

(b) Compatibility equations



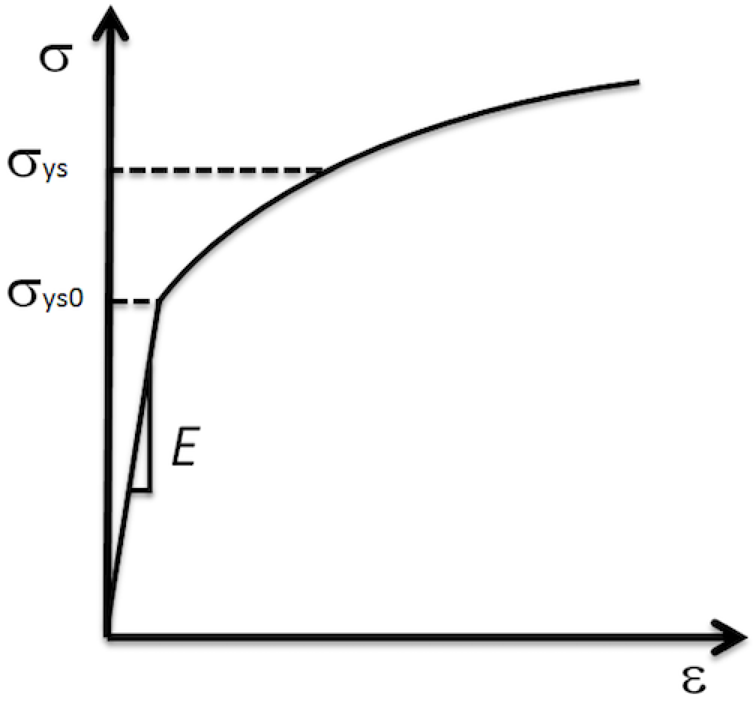
(a) Original (b) Non-compatible (c) Compatible

Strain to displacement relationship:

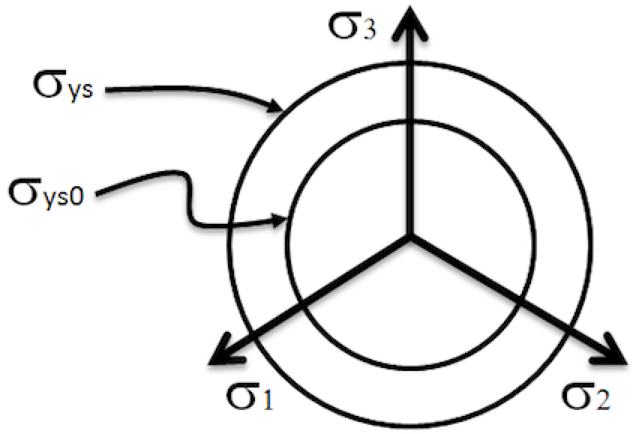
$$\varepsilon_x = -\frac{\partial u}{\partial x}; \quad \varepsilon_y = -\frac{\partial v}{\partial y}; \quad \varepsilon_z = -\frac{\partial w}{\partial z}$$

$$\gamma_{xy} = -\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}; \quad \gamma_{yz} = -\frac{\partial w}{\partial y} - \frac{\partial v}{\partial z}; \quad \gamma_{xz} = -\frac{\partial w}{\partial x} - \frac{\partial u}{\partial z}$$

(c) Constitutive law



Uniaxial stress-strain curve



Yield surface in principal stress-space

Constitutive law

$$\boldsymbol{\Delta\sigma} = f_m(\boldsymbol{\Delta\varepsilon})$$

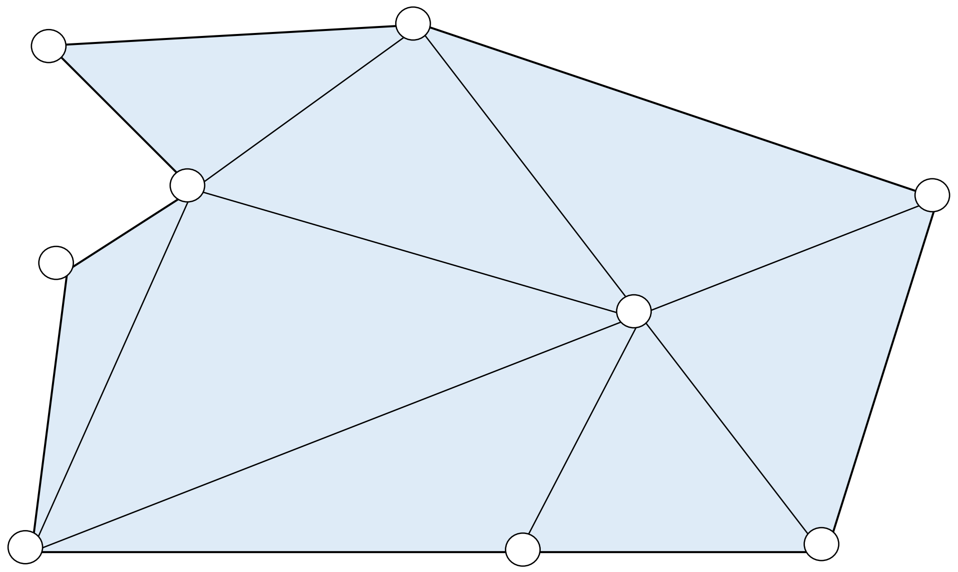
$$\begin{Bmatrix} \Delta\sigma_x \\ \Delta\sigma_y \\ \Delta\sigma_z \\ \Delta\tau_{xy} \\ \Delta\tau_{xz} \\ \Delta\tau_{zy} \end{Bmatrix} \qquad \begin{Bmatrix} \Delta\varepsilon_x \\ \Delta\varepsilon_y \\ \Delta\varepsilon_z \\ \Delta\gamma_{xy} \\ \Delta\gamma_{xz} \\ \Delta\gamma_{zy} \end{Bmatrix}$$

Stress increment

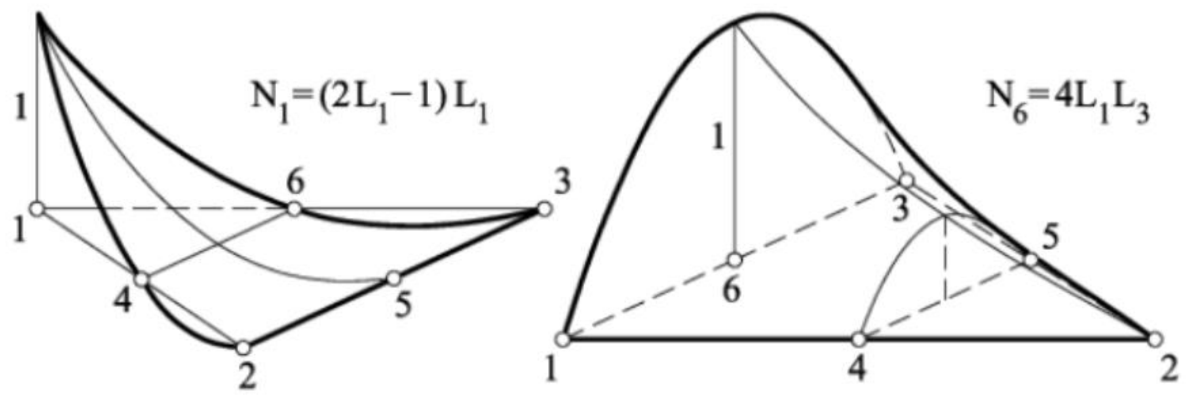
Strain Increment

Finite element method (FEM)

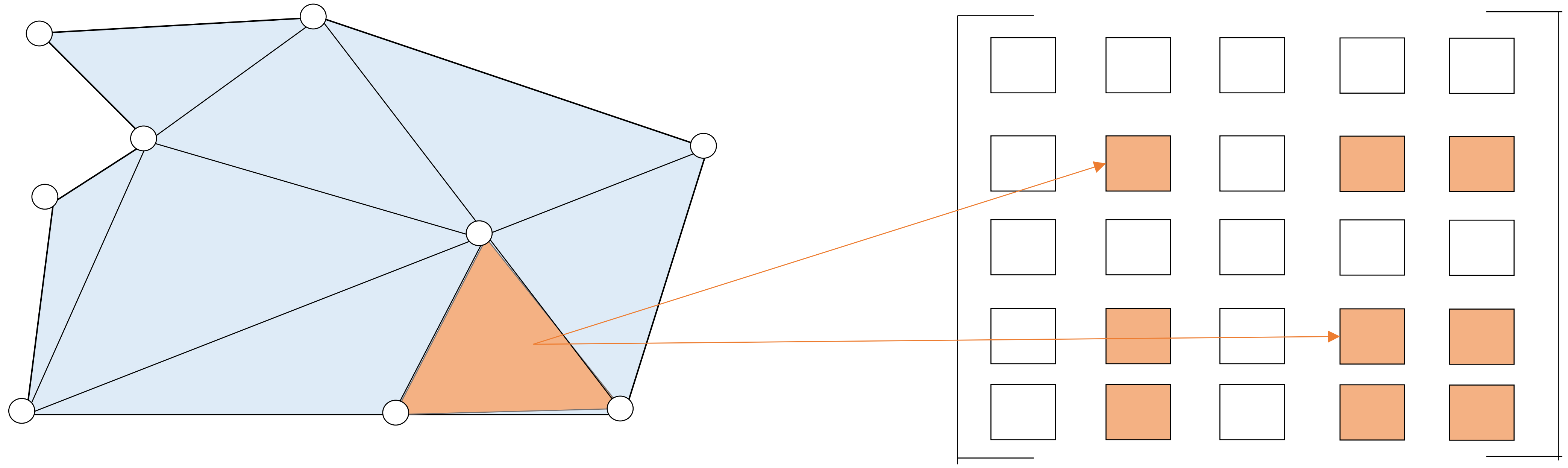
Reformulating the PDE system to an easily solvable system of algebraic equations!!



Step 1: Discretize the continuum

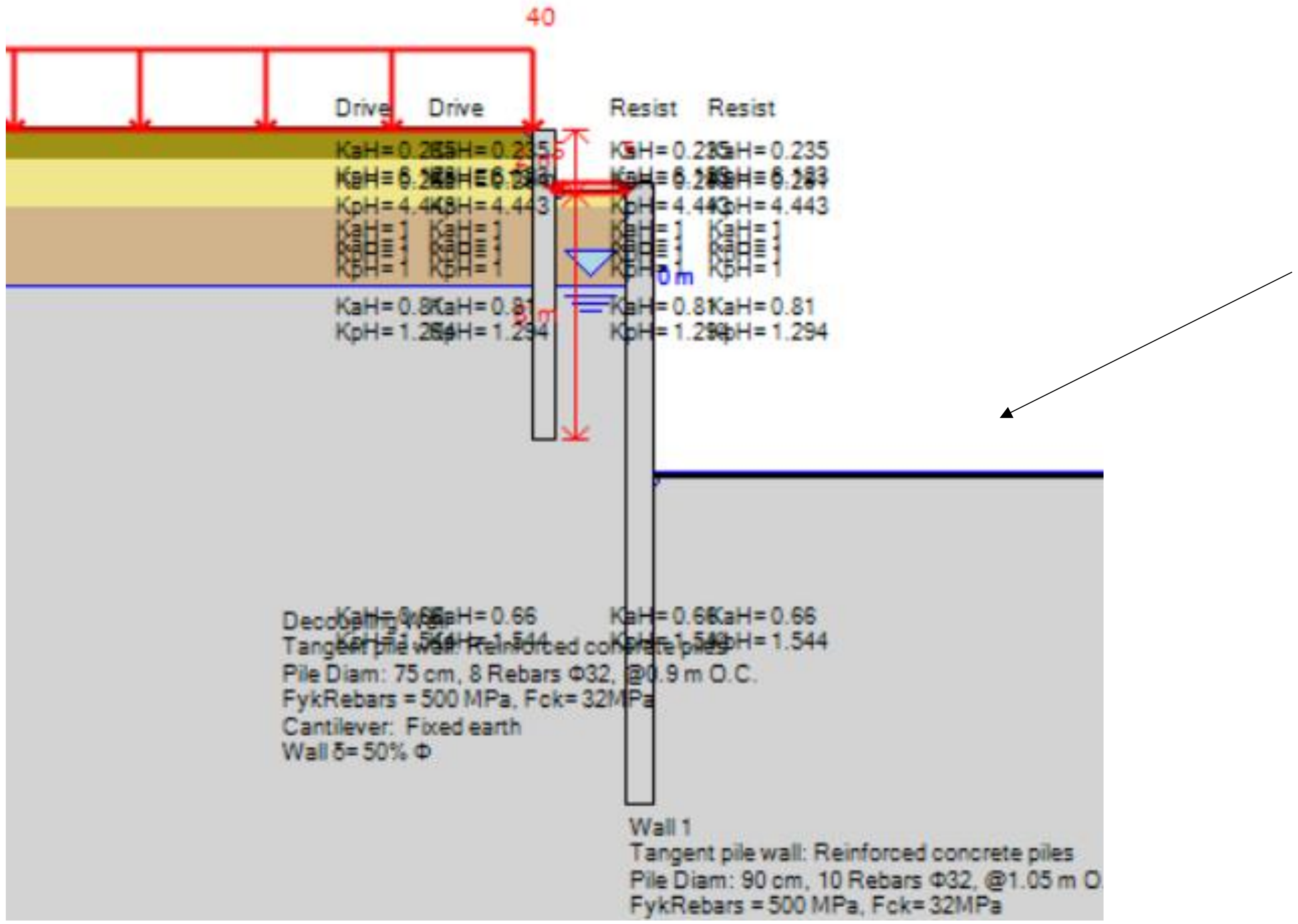


Step 2: Select interpolation functions



Step 3: Assemble the global equation system

Soil Pressure Methods (LEM Analysis)



Excavation to install oil separator tanks next to preexisting wall

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Part 2

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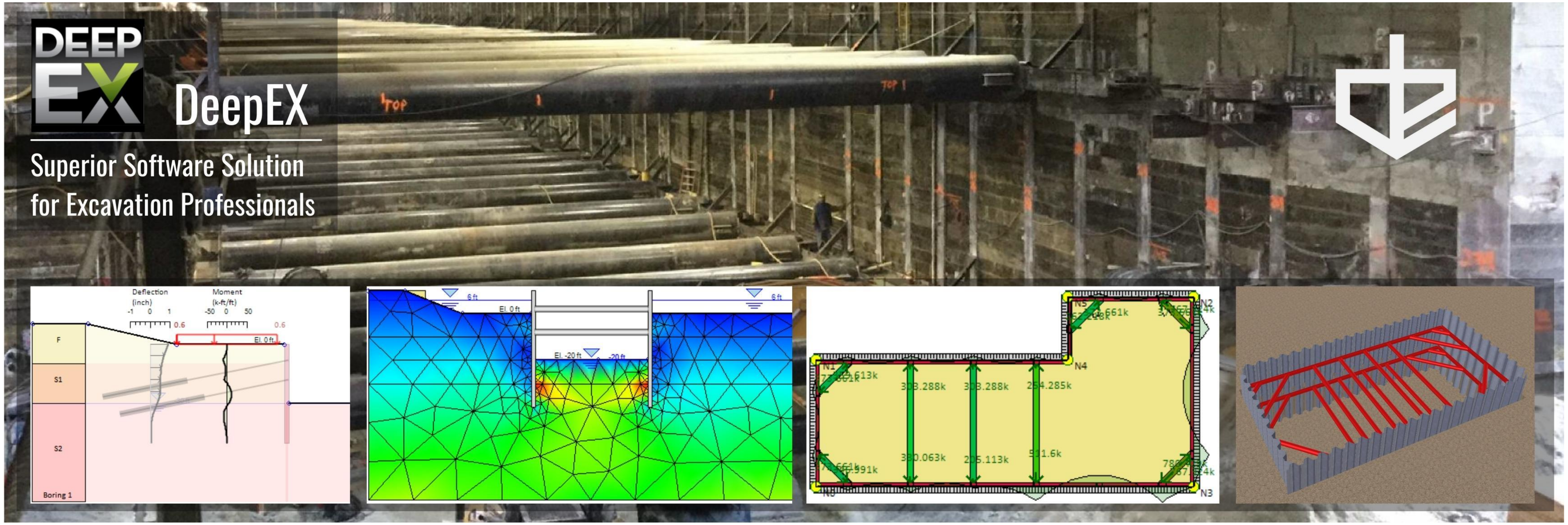
DeepEX Features & Capabilities



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DeepEX Features & Capabilities

DeepEX Software - General Capabilities

Full Structural and Geotechnical Design of any Deep Excavation Model

Wall Types in DeepEX

- ✓ Soldier Pile and Lagging Walls
- ✓ Sheet Pile Walls
- ✓ Secant / Tangent Pile Walls
- ✓ Concrete Diaphragm Walls (Slurry Walls)
- ✓ Soldier Pile and Tremied Concrete Walls
- ✓ Combined Sheet Pile Walls (King Piles)
- ✓ Box Sheet Pile Walls
- ✓ Custom Walls

Support Systems in DeepEX

- ✓ Anchored Walls (Tiebacks and Helical Anchors)
- ✓ Braced Excavations (Steel Struts and Rakers)
- ✓ Top/Down Excavations with Concrete Slabs
- ✓ Dead-man Walls
- ✓ Bin-Type Walls
- ✓ Cofferdams
- ✓ Circular Shafts
- ✓ Cantilever Walls

ANALYSIS METHODS: LIMIT EQUILIBRIUM ANALYSIS

Soil Pressures: Active/Passive, At-rest, Apparent Pressures (FHWA, Peck, Adaptive, Custom Trapezoidal +more)

Beam Analysis: Blum's, FHWA Simple Span, CALTRANS +more

NON-LINEAR ANALYSIS (SOIL SPRINGS)

Moments and Reactions from Spring Analysis

Cumulative Results from Stages

Realistic Displacements

FINITE ELEMENT ANALYSIS

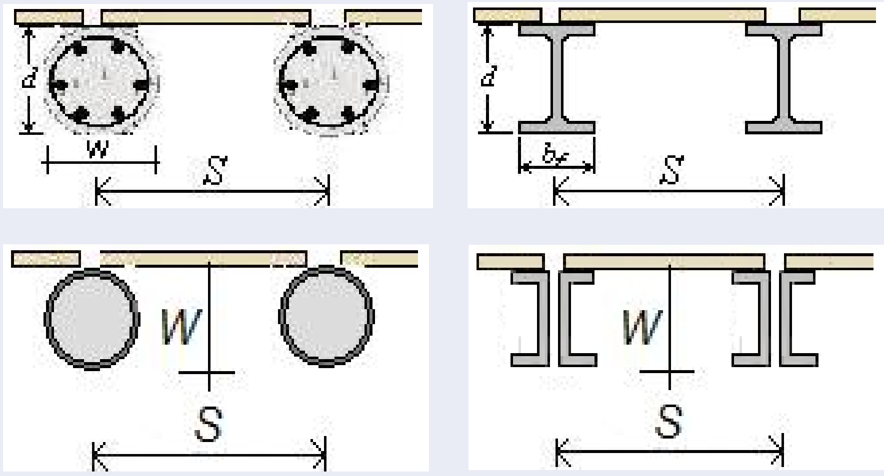
Moments and Reactions from Finite Elements

Full Soil-Structure Interaction

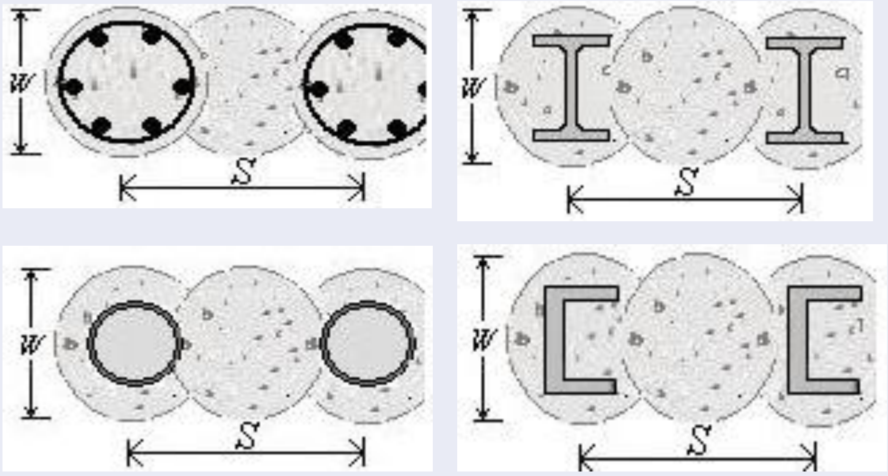
Calculate Surface Settlements

Common Wall Types in DeepEX

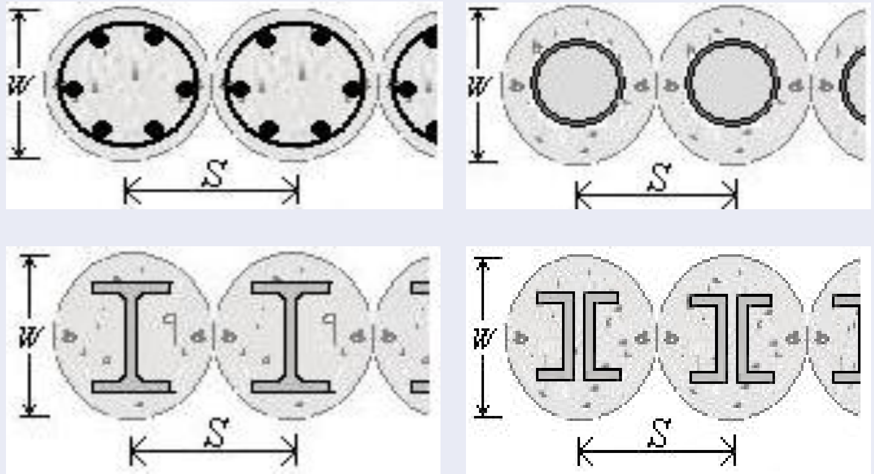
Soldier pile and lagging walls



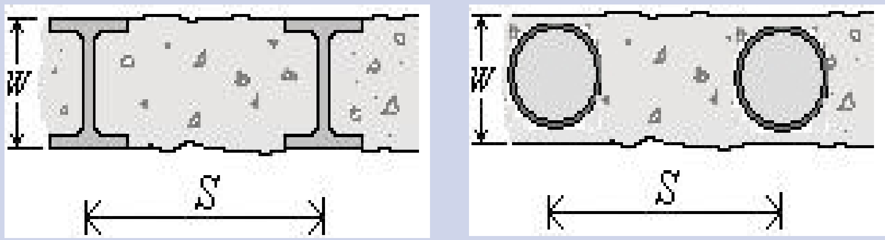
Secant pile walls



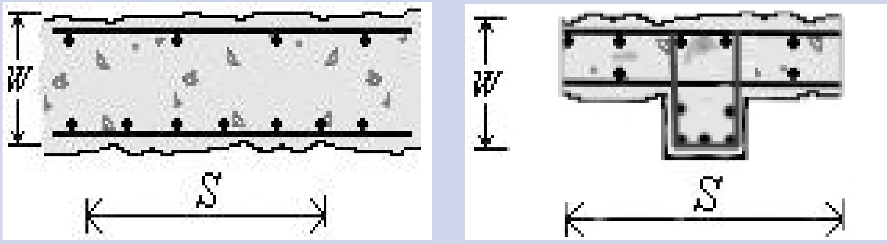
Tangent pile walls



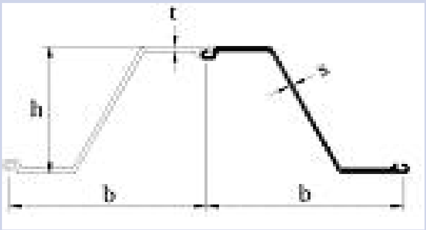
SPTC walls



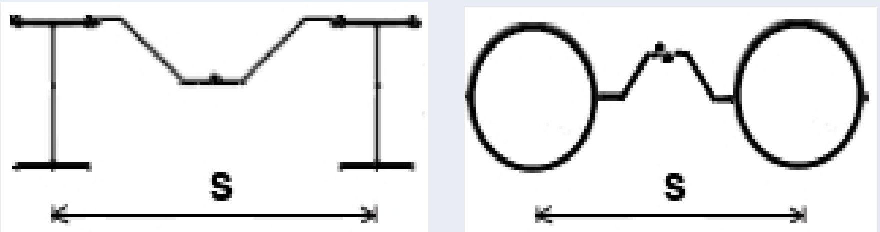
Diaphragm (slurry) walls



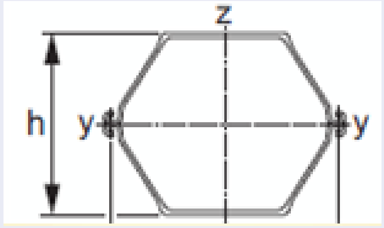
Sheet pile walls



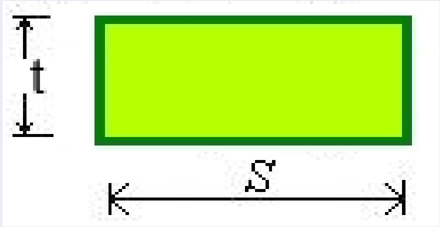
Combined sheet pile walls



Box sheet pile walls



Custom walls



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Support Systems in DeepEX

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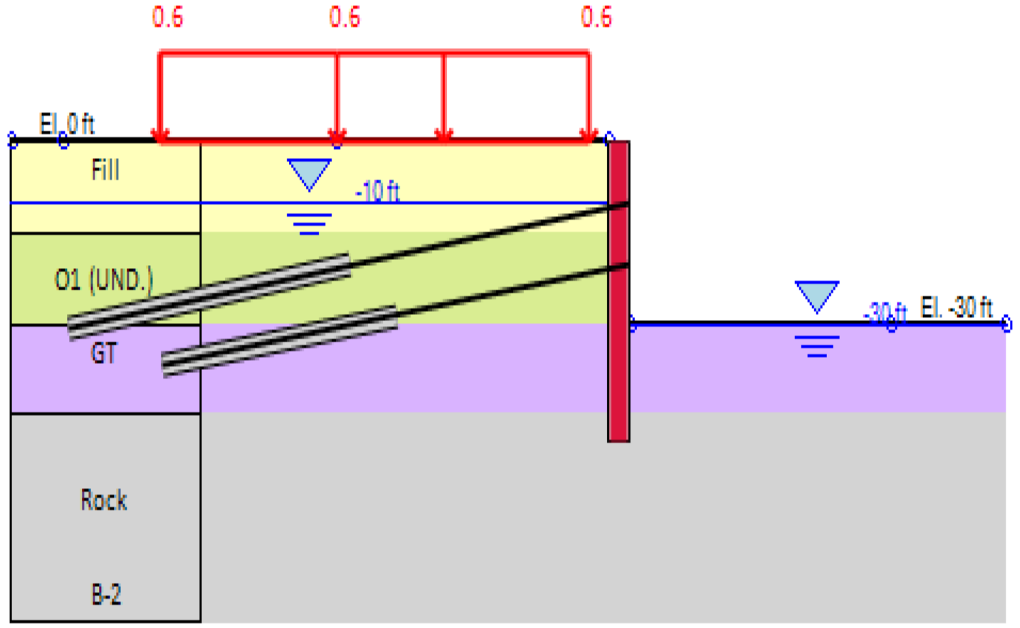
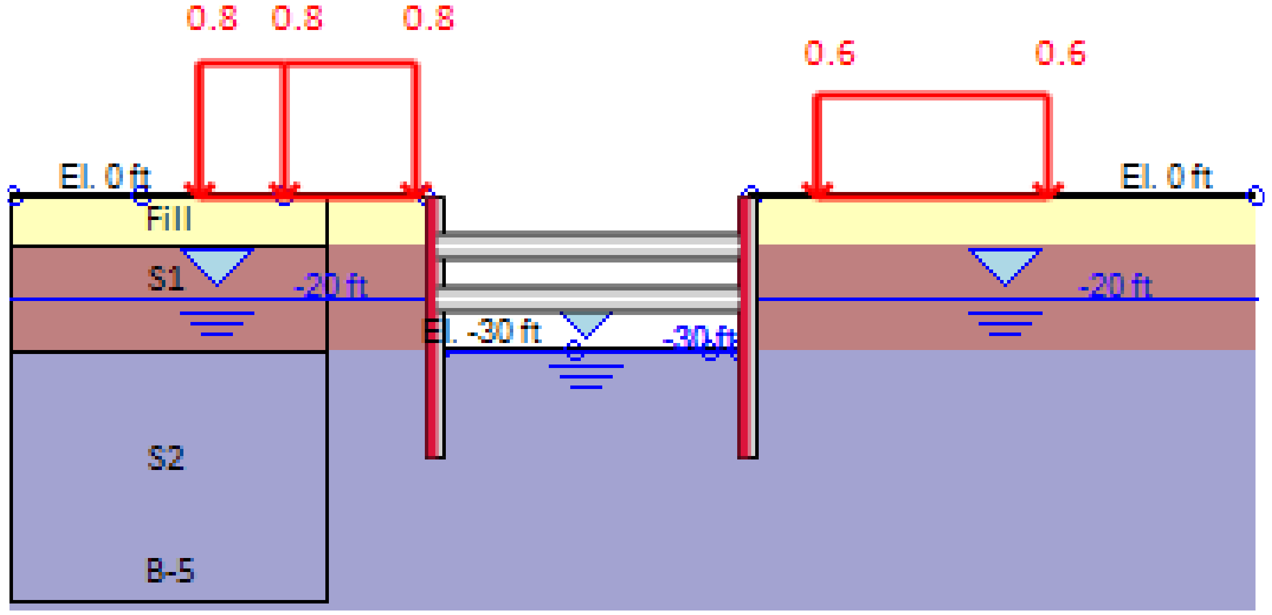
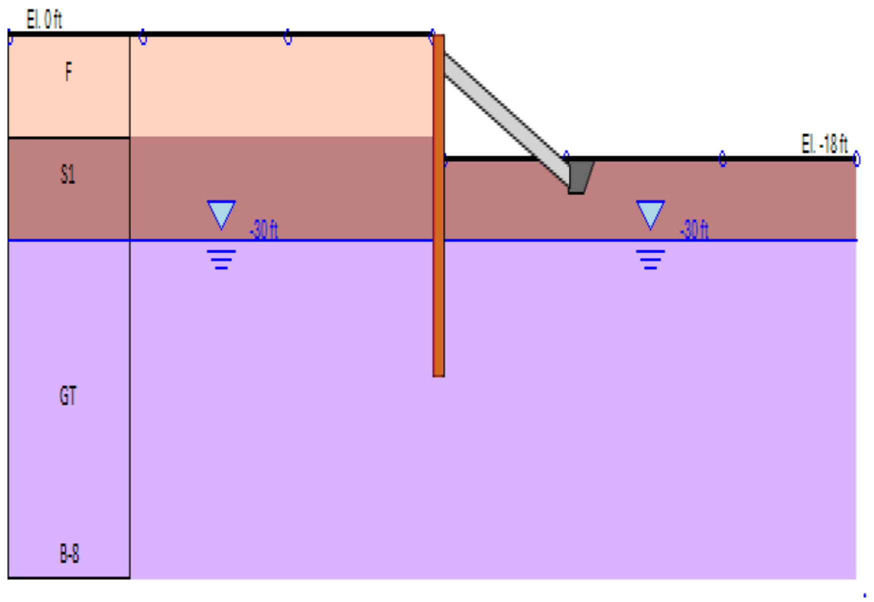
Anchored Walls (Tiebacks)

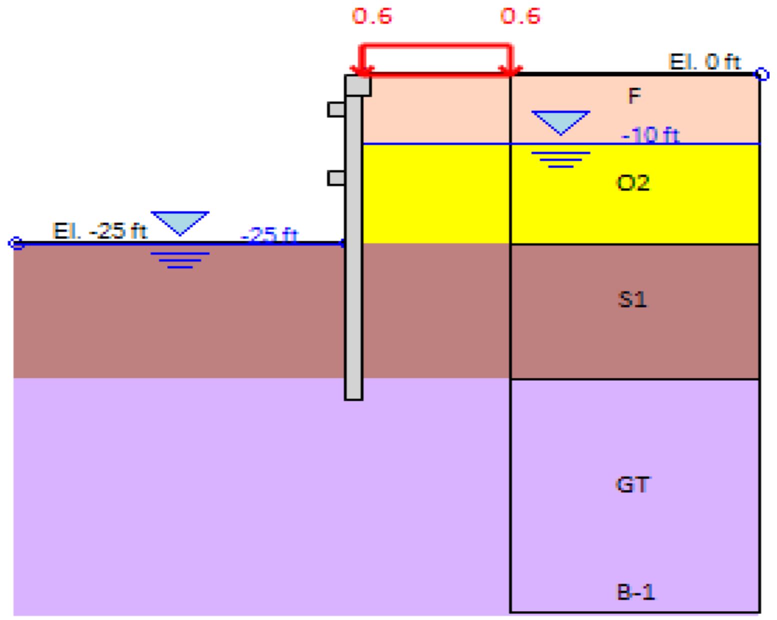


Braced Excavations (Struts and Rakers)

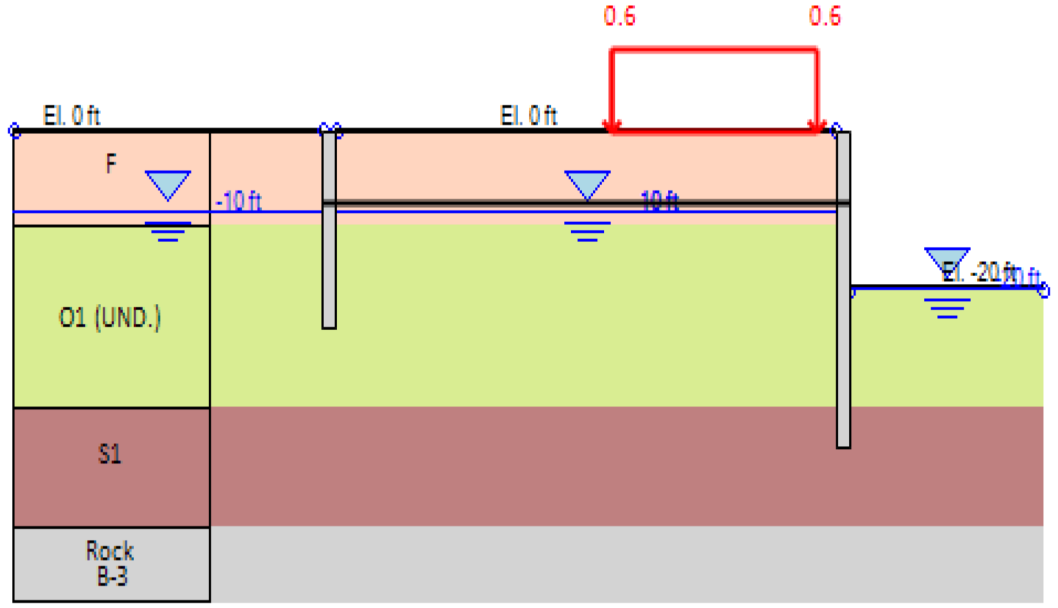




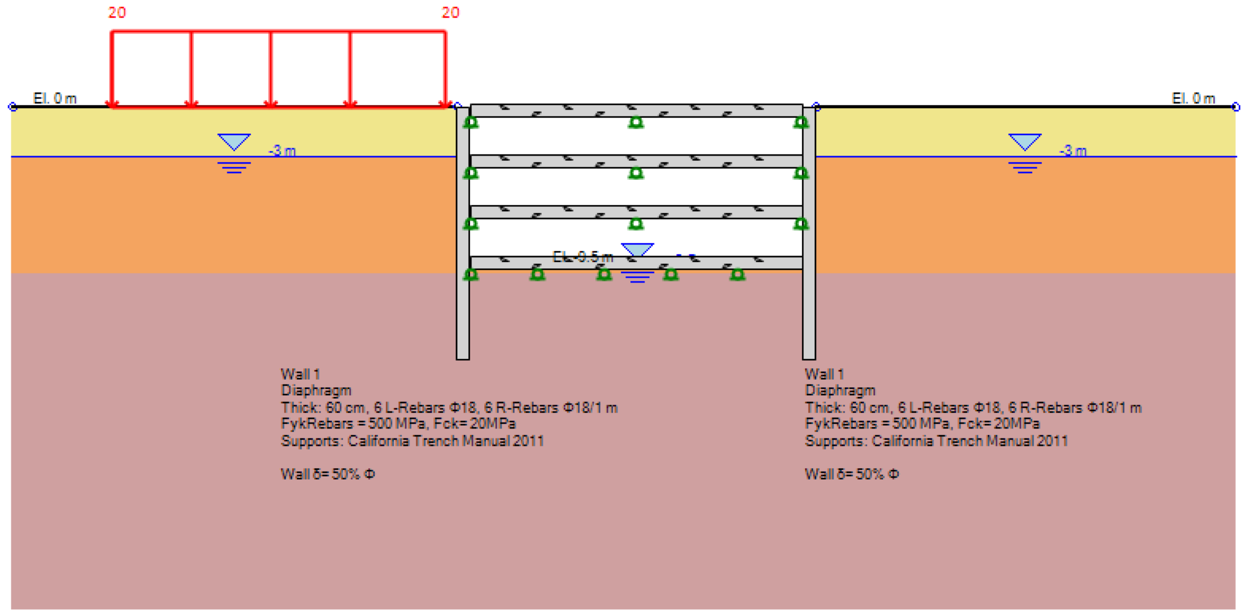
Circular Shafts (Ring Beams)



Dead-man Walls (Tierods)



Top-Down Excavations (Concrete Slabs)



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Multiple Analysis Methods

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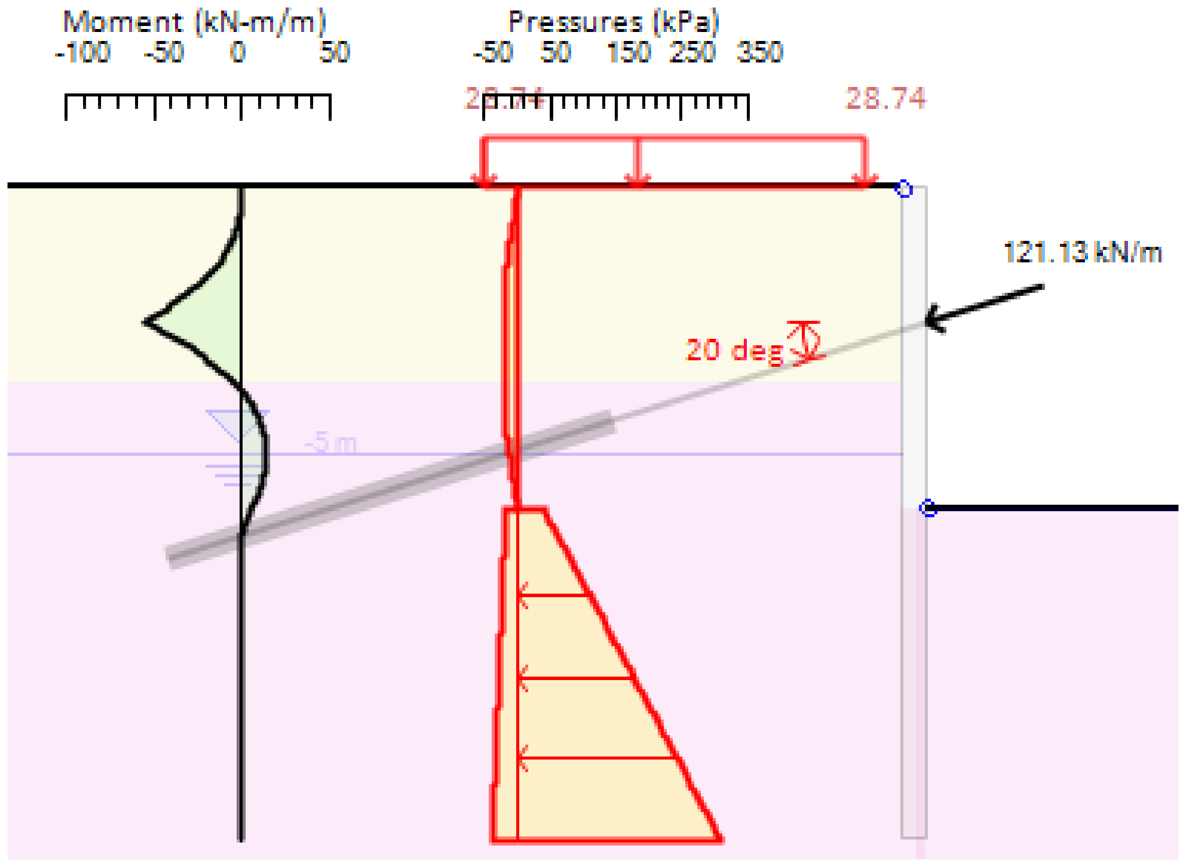
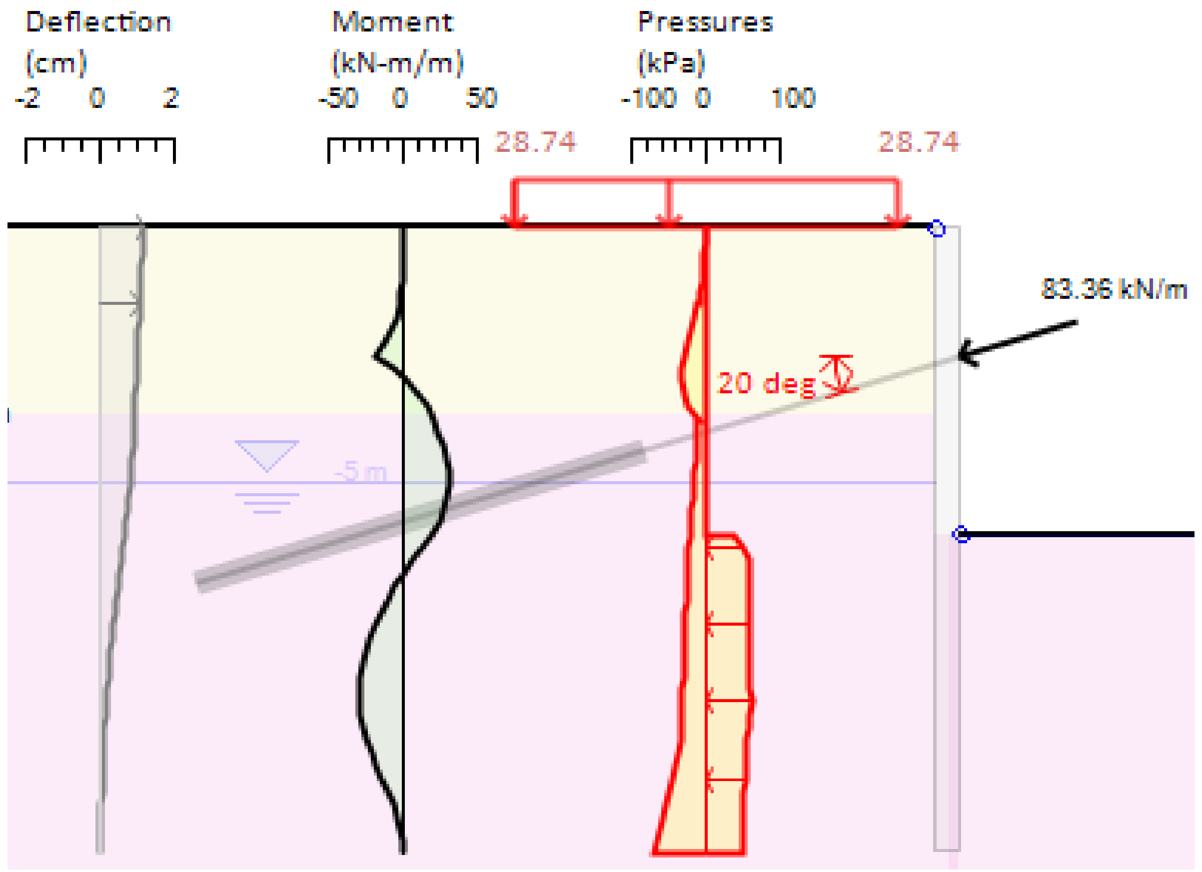
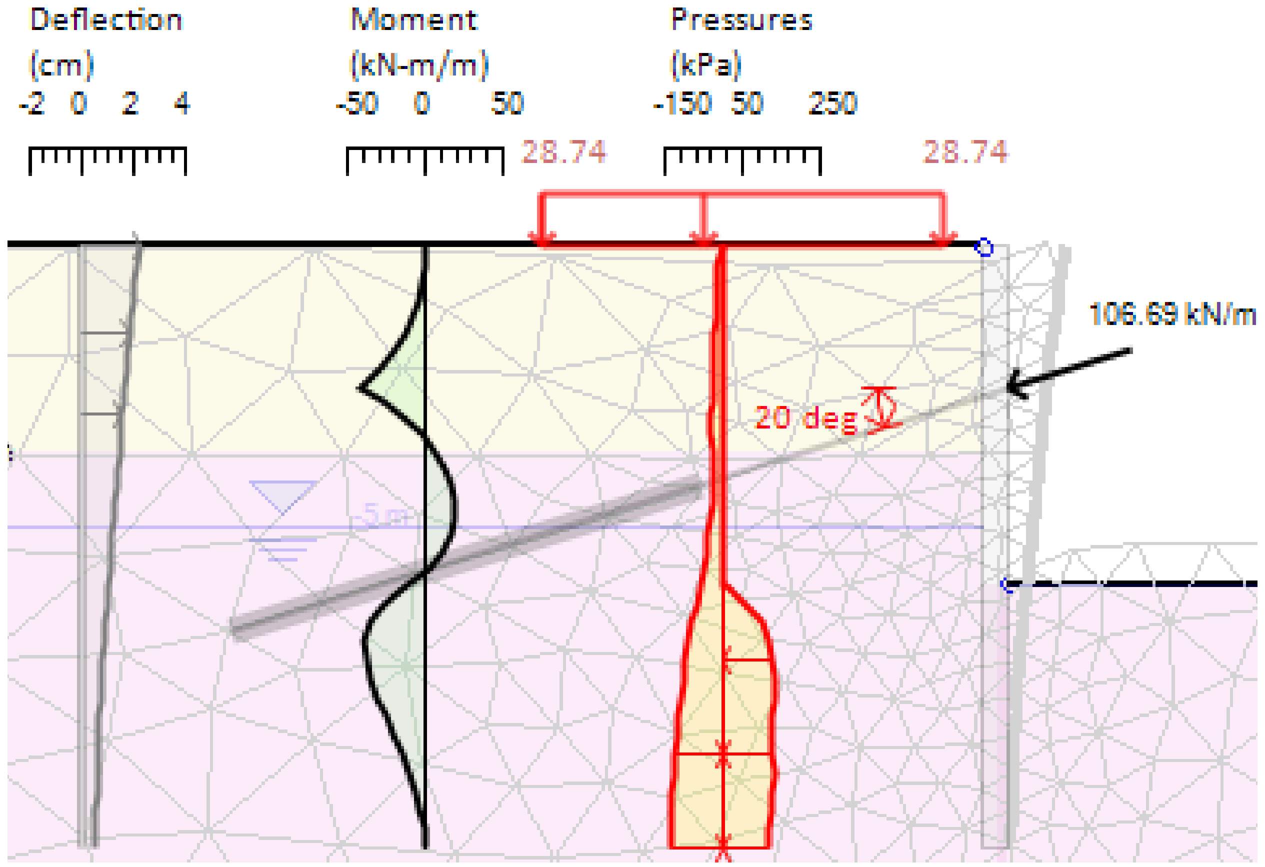
Limit Equilibrium Analysis (LEM)



Non-Linear Analysis (NL) (Elastoplastic Springs)



Finite Element Analysis (FEM)



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Structural & Geotechnical Design

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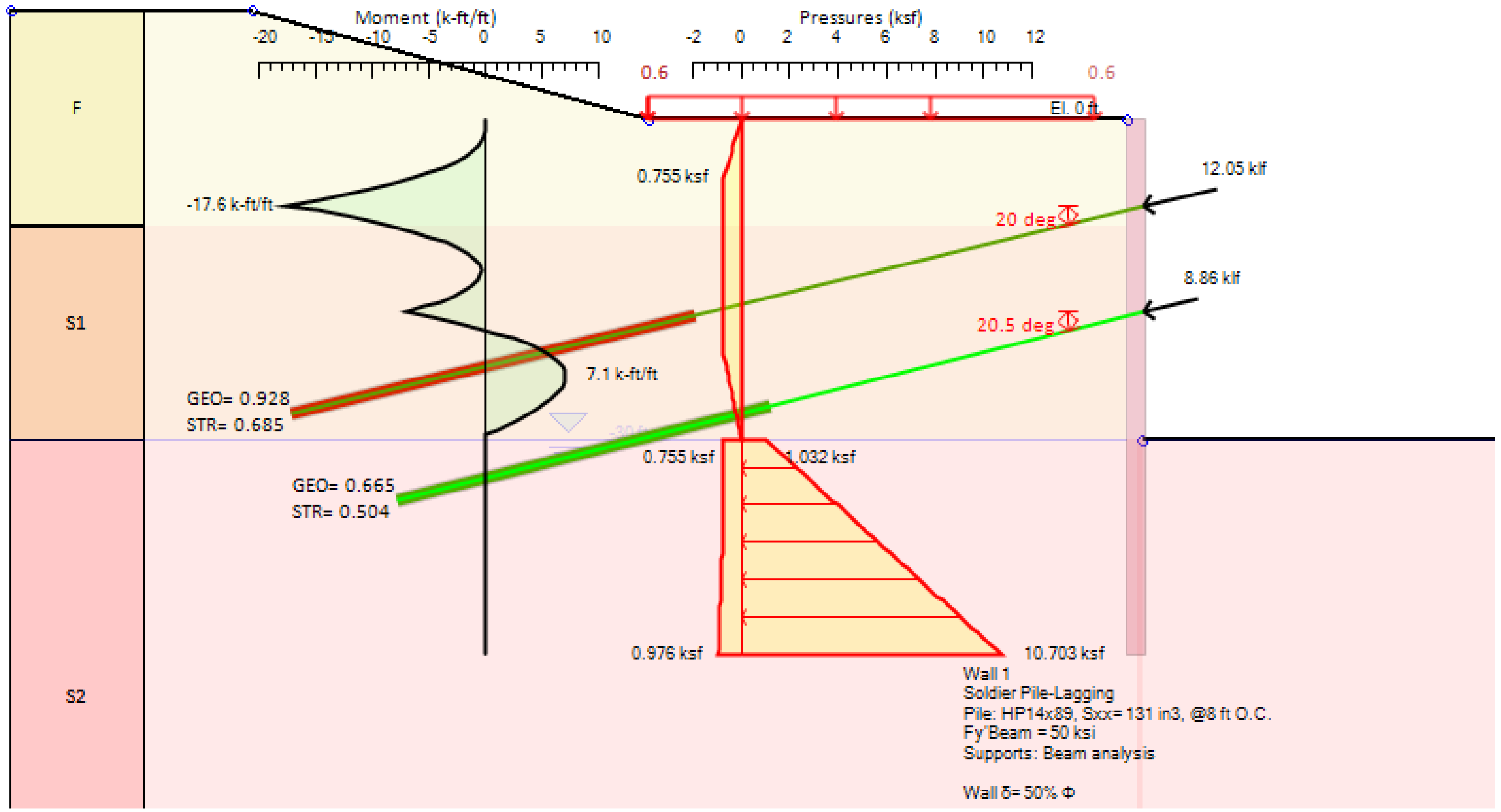
Diagrams, Reactions & Check Ratios:



Structural Checks & Design Calculations:

calculations

Axial stress: fa= P/A = 0/26.1= 0k/in^2

Bending stress in X-X: fbx= |Mxx + MxxDL|/Sxx = |140.82+0| x 12 in/ft /131in3= 12.9k/in^2

Bending stress in Y-Y: fby |Myy + MyyDL|/Syy = |0+0| x 12 in/ft /44.3in3= 0k/in^2

SECTION: HP14x89 Section is W or I beam

Dead Load Moments: MxDL= 0 k-ft, MyDL= 0 k-ft

Classify section flange for compact/noncompact status, Table B4.1

$$\lambda = \frac{0.5\ b\ f}{t\ f} = 11.951$$

Classify section flange for compression, Table B4.1

$$\lambda_r = 0.56 \sqrt{\frac{E\ steel}{f\ y}} = 13.487$$

Structural Codes: Eurocodes 1,2 & 8, ACI, LRFD, AISC, AS 3600 & 4100, CN (China) + more

Design Standards: Eurocode 7, DIN, BS, XP, AASHTO LRFD, CALTRANS, CN (China) + more

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Soil Types & Stratigraphy

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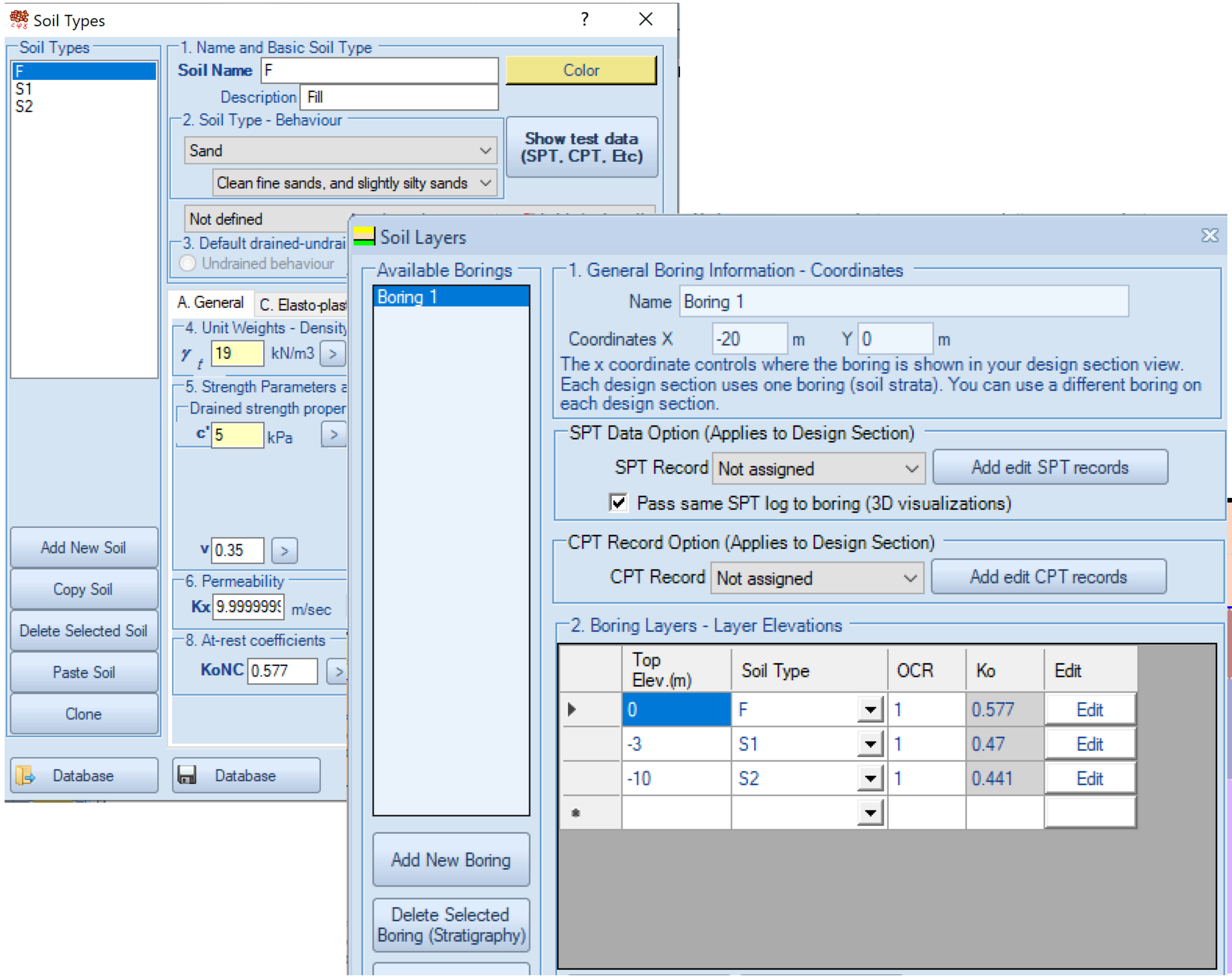
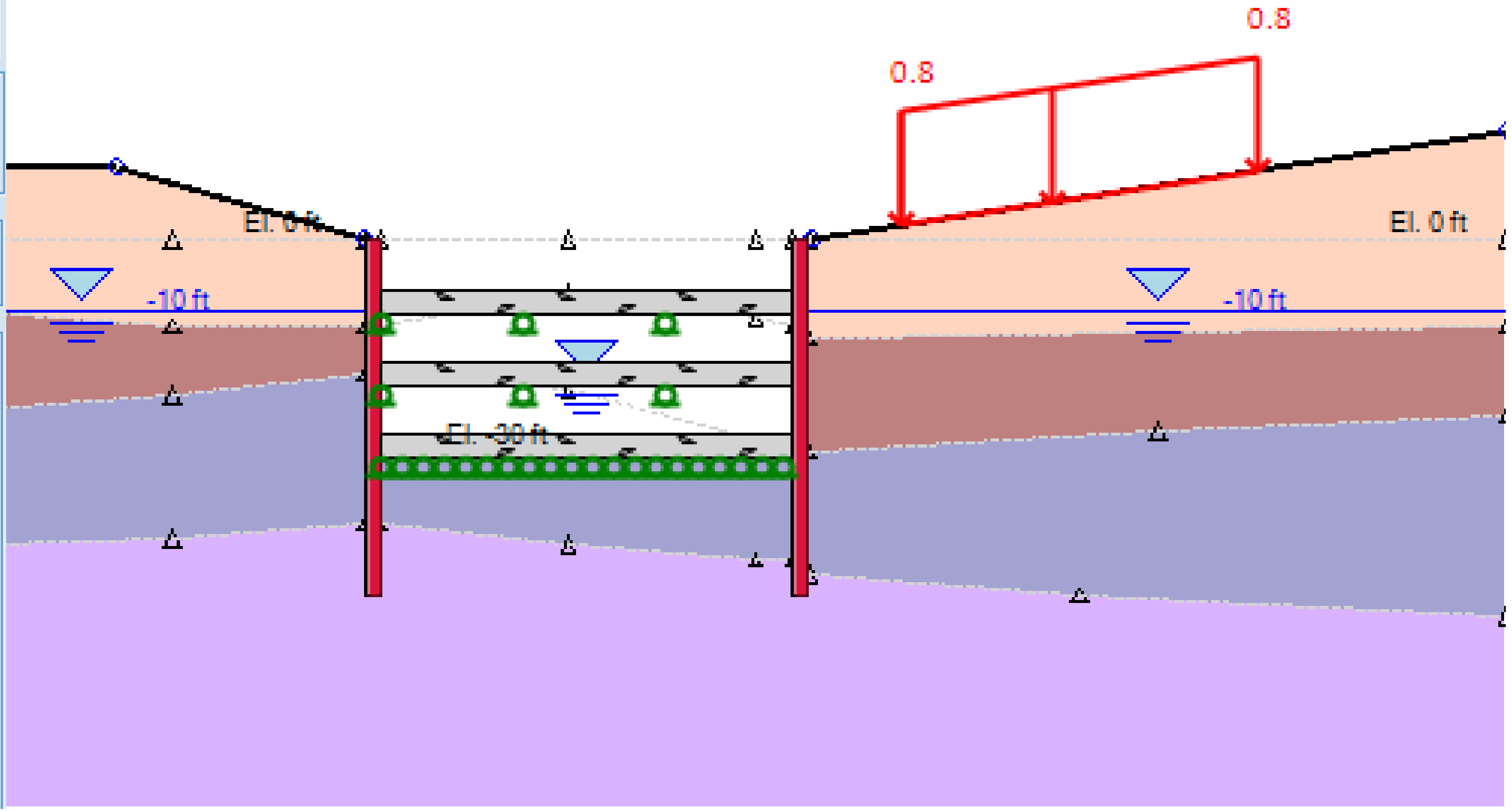
- ✓ Create multiply soil types and define soil properties
- ✓ Soil properties estimation tools (NSPT values - test data)
- ✓ Create multiple borings and define the horizontal stratigraphy
- ✓ Add CPT logs and SPT Records - Estimate properties from records
- ✓ Custom Layer mode: Create inclined soil layers
- ✓ Soil Change Commands: Change soil properties through stages





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Include All Construction Stages

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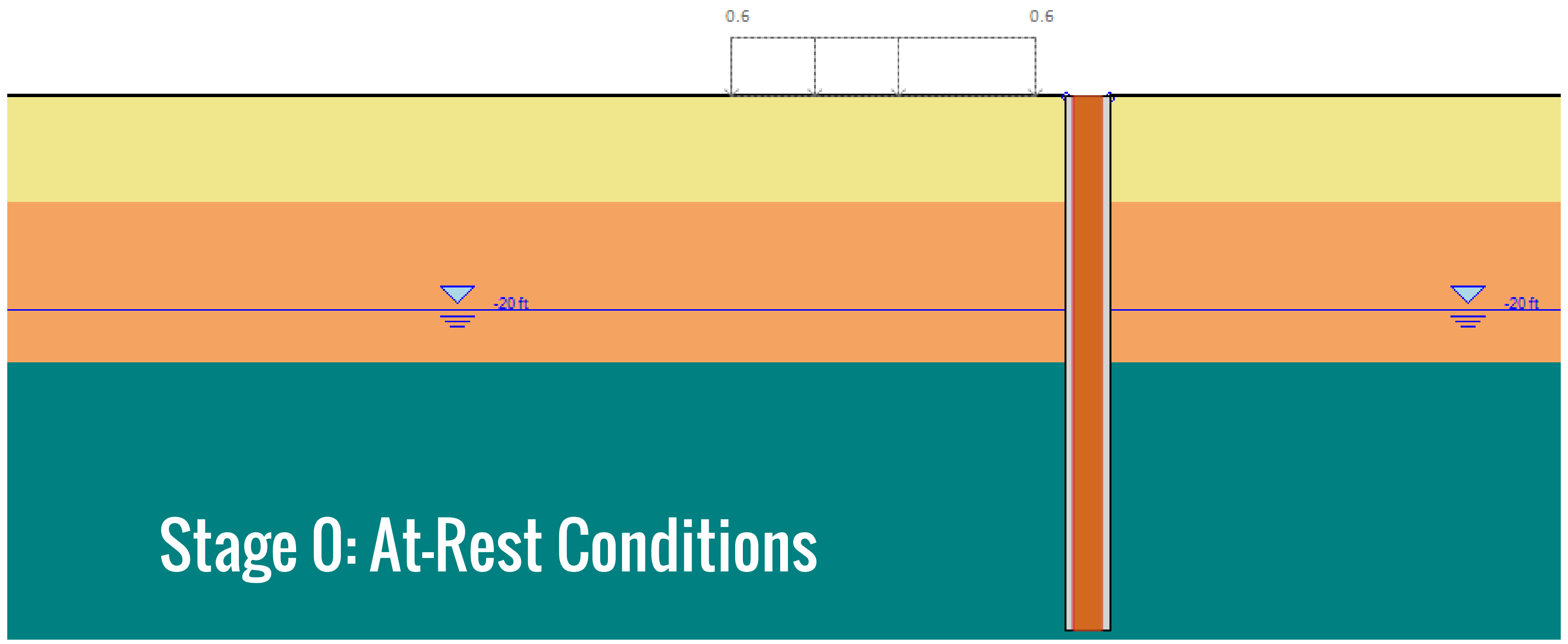
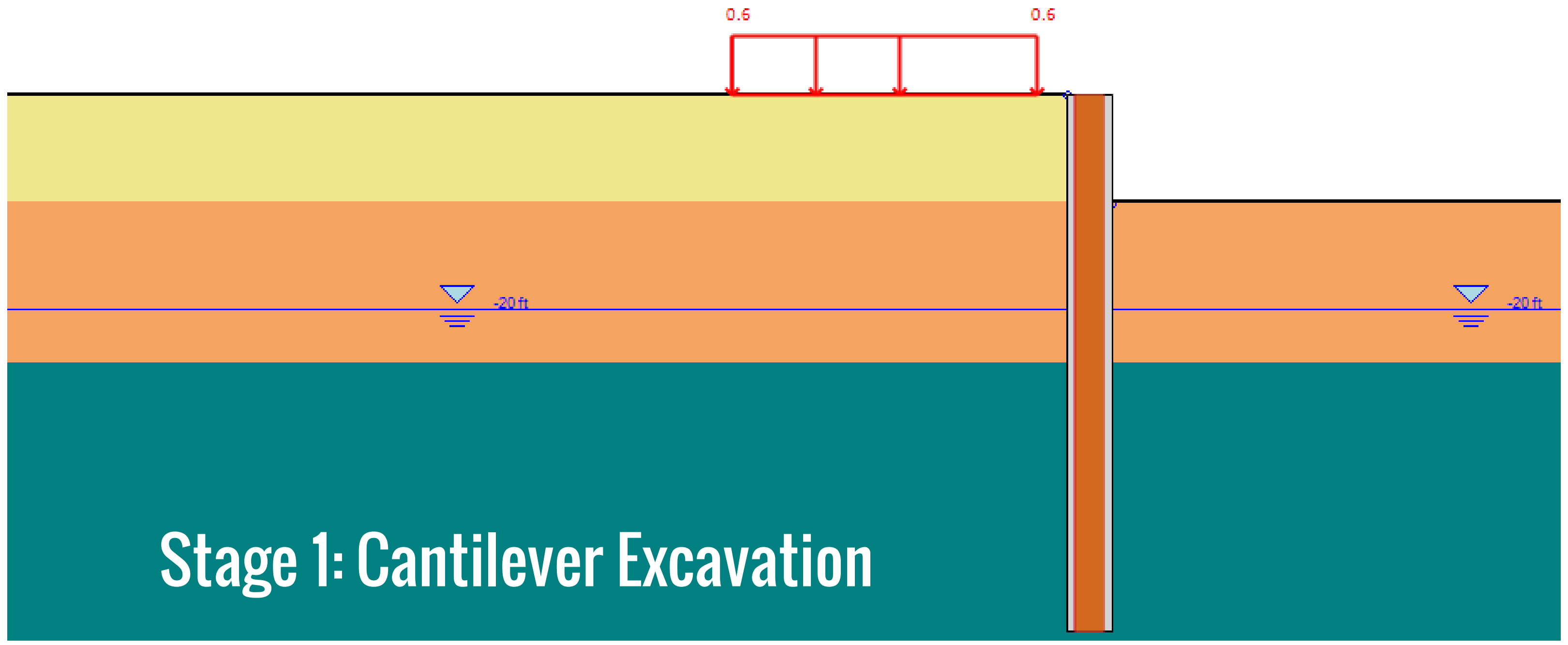
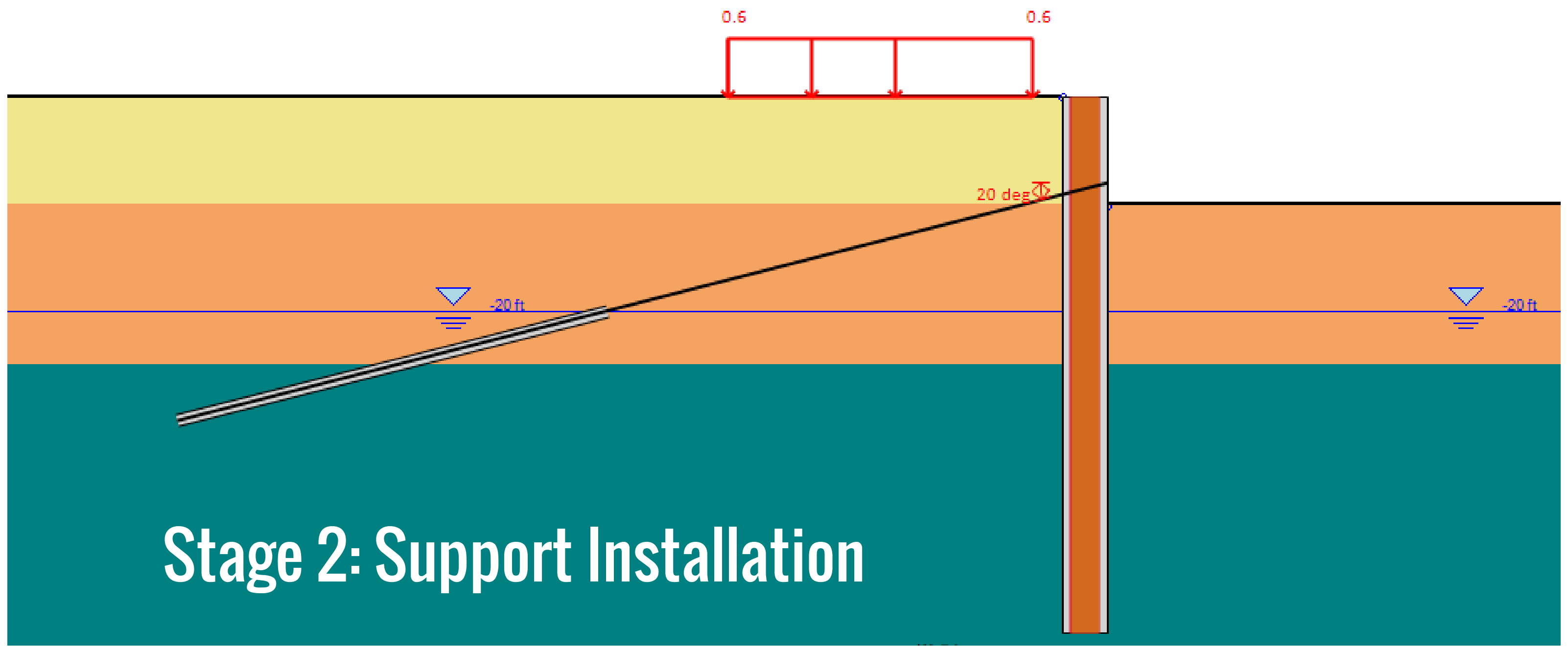
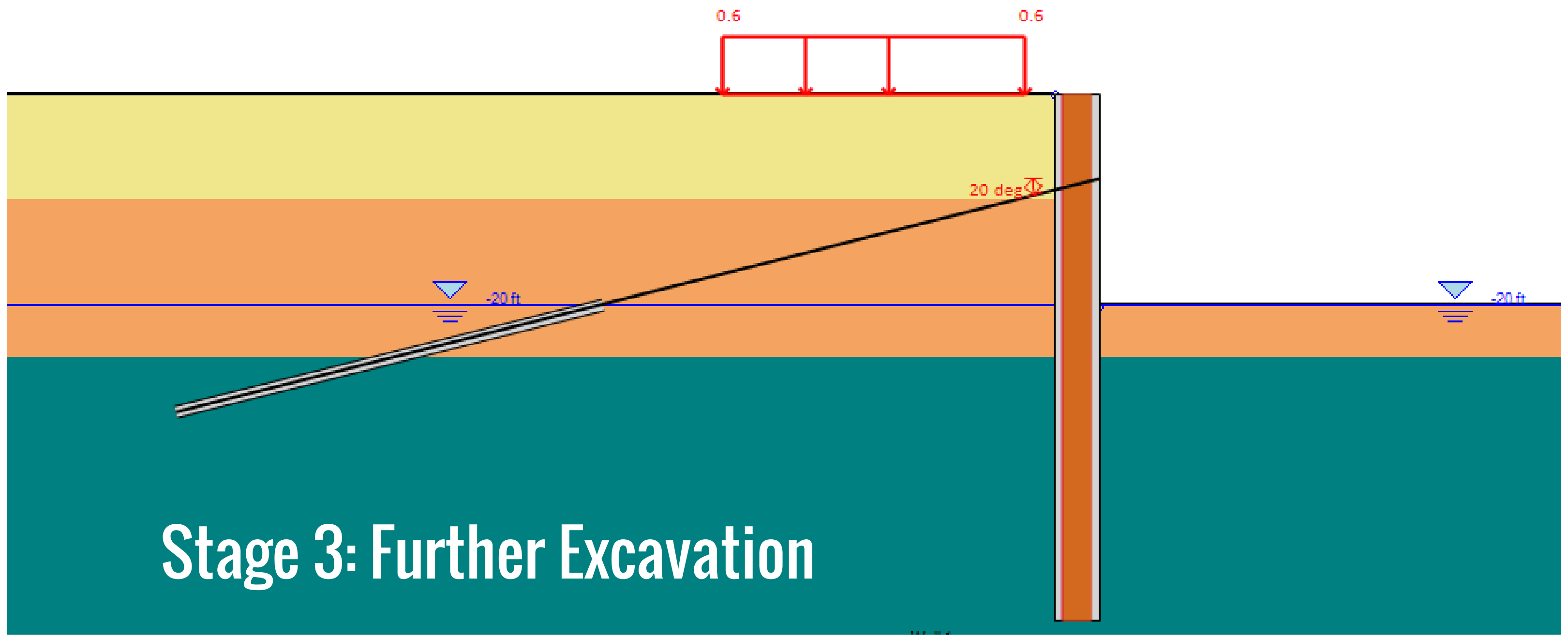
- ✓ Create all intermediate construction stages
- ✓ Review the results for each stage & recognize the critical stages
- ✓ Perform an efficient model optimization
- ✓ Get more realistic results for methods that consider staging (NL, FEM)









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Limit Equilibrium Analysis Concept (LEM)

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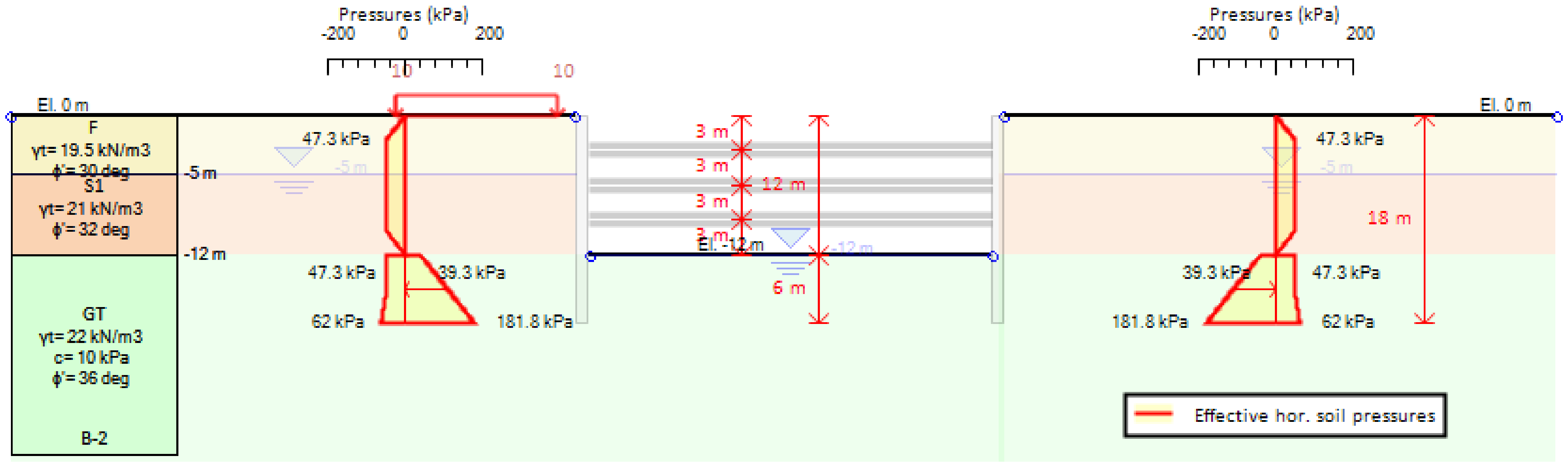
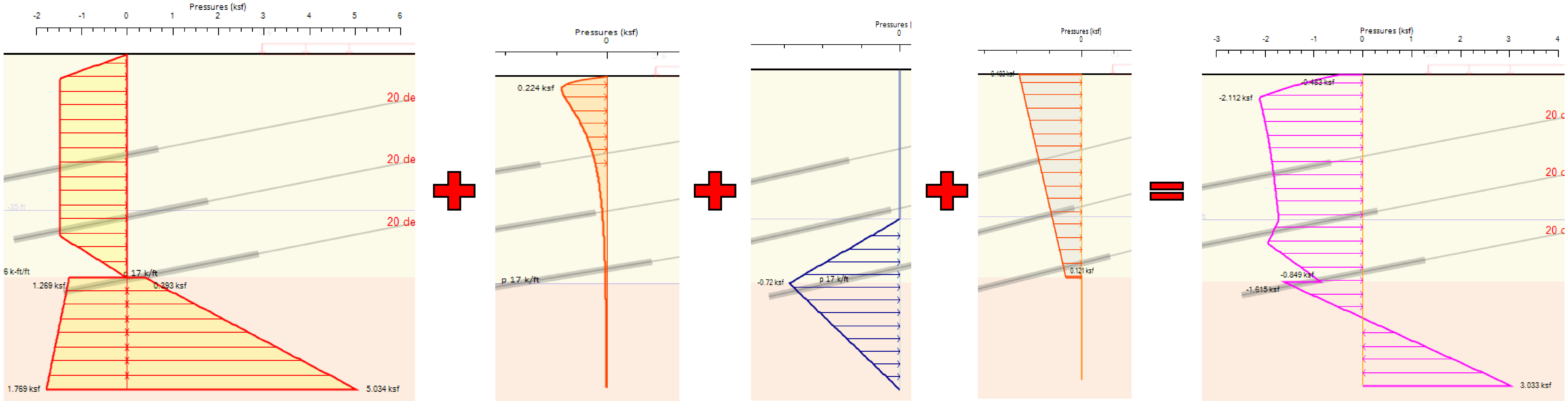
- ✓ Assume lateral earth pressures.
- ✓ Determine fixity locations for forces at subgrade.
- ✓ Analyze wall beam with assumed loads.
- ✓ Advantages: Easy method to verify. Gives a back check for more rigorous methods.
- ✓ Disadvantages: Soil-structure interaction ignored.





Soil Pressures + Surcharge + Water Pressures + Seismic Pressures = Net Pressures

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Soil Pressure Methods (LEM Analysis)

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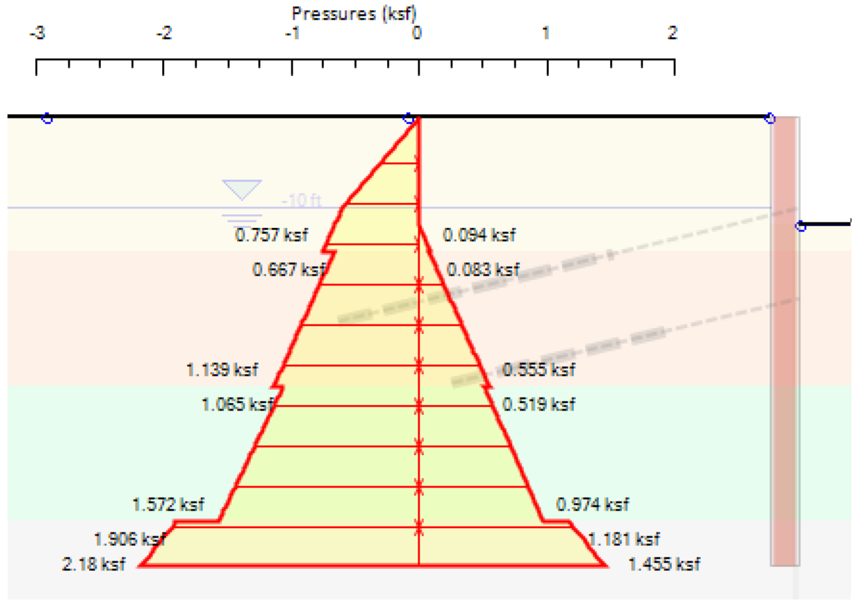
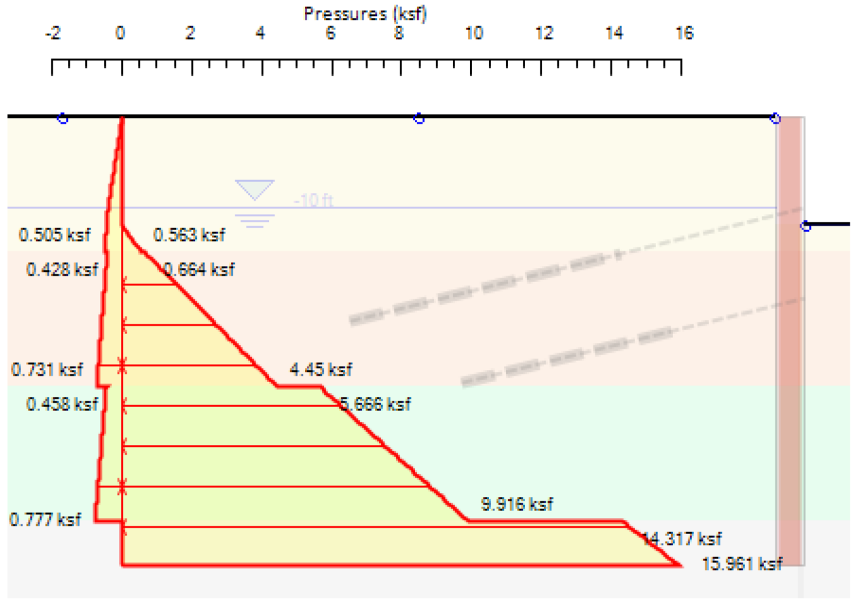
Cantilever Excavations

At-Rest Pressures

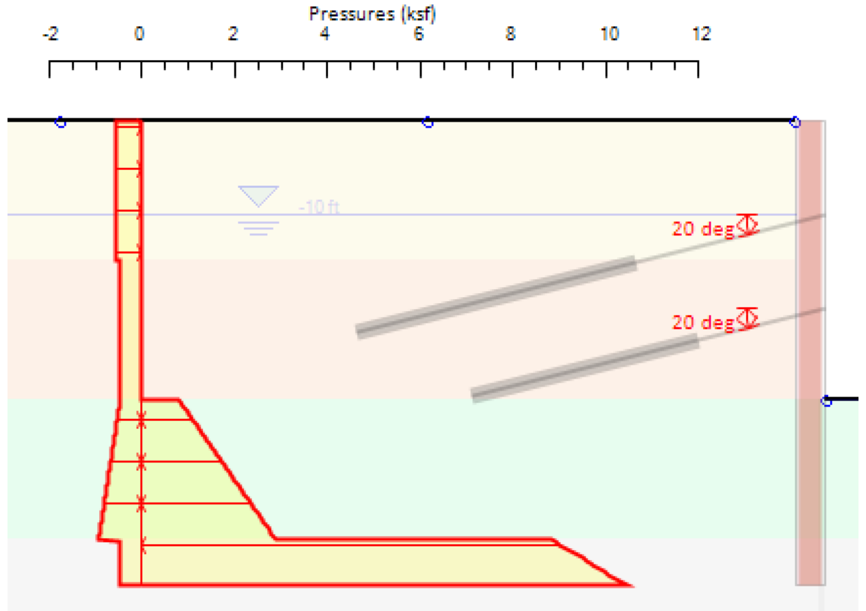


Active - Passive Pressures

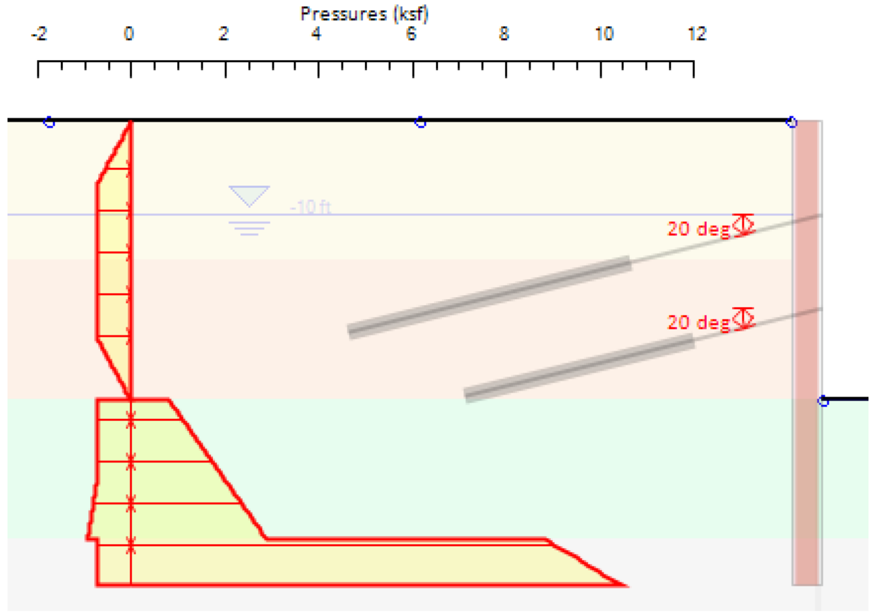


Construction Stages with multiple support levels

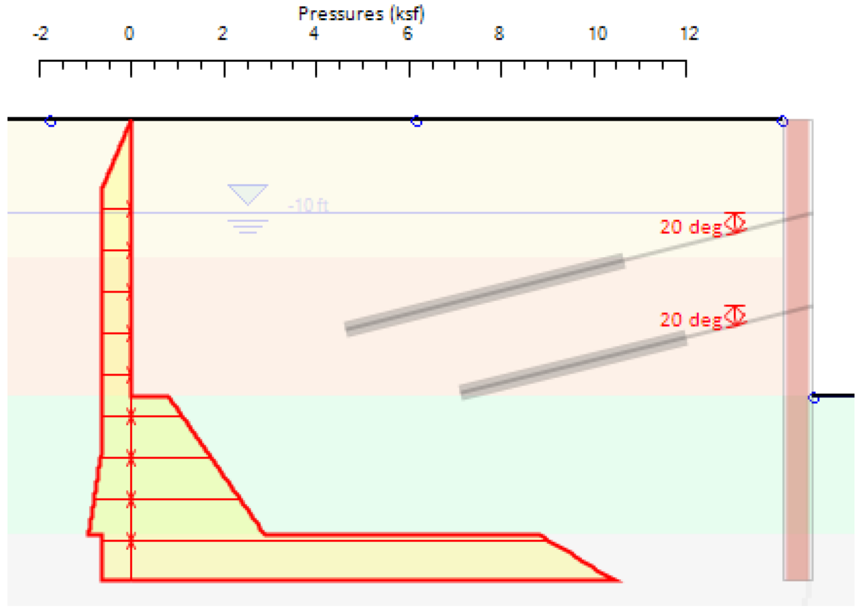
Peck 1969 Pressures



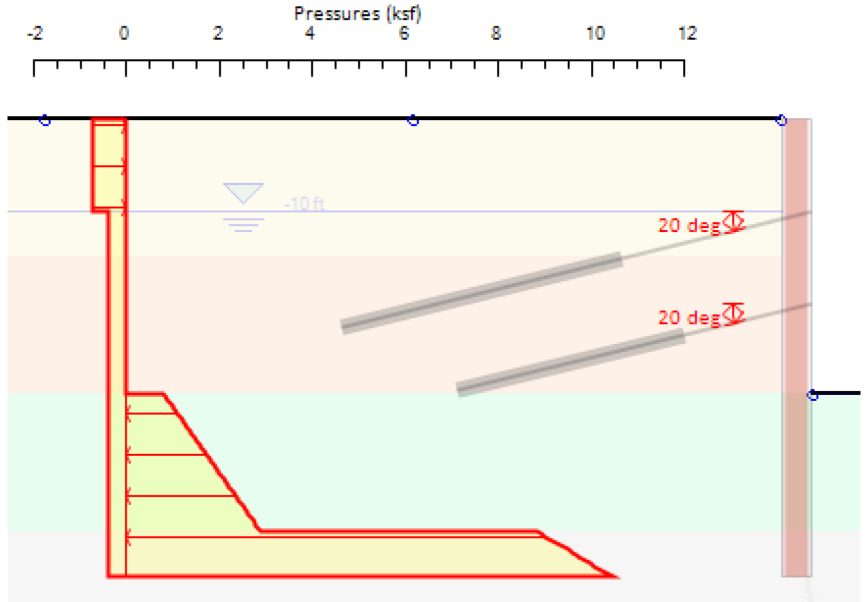
FHWA Apparent Pressures



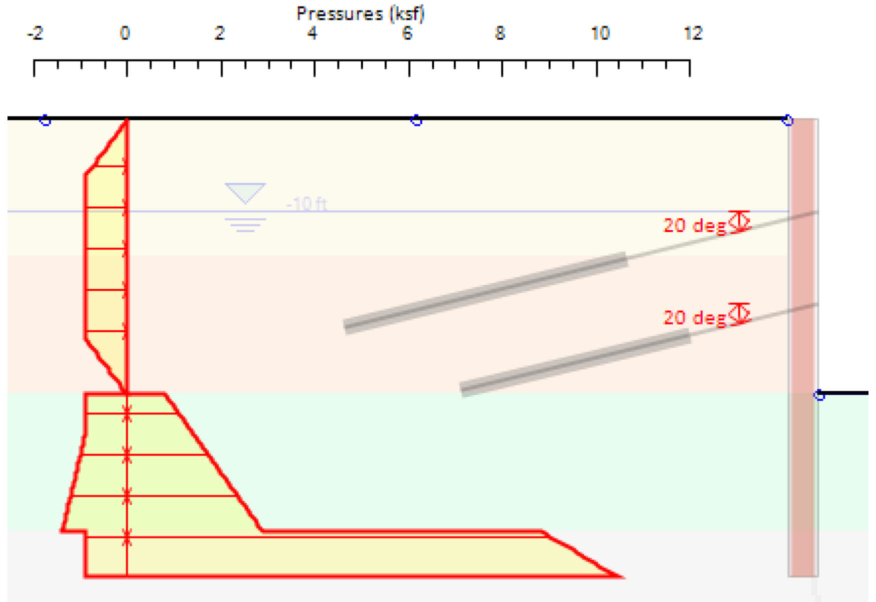
Custom Trapezoidal Pressures



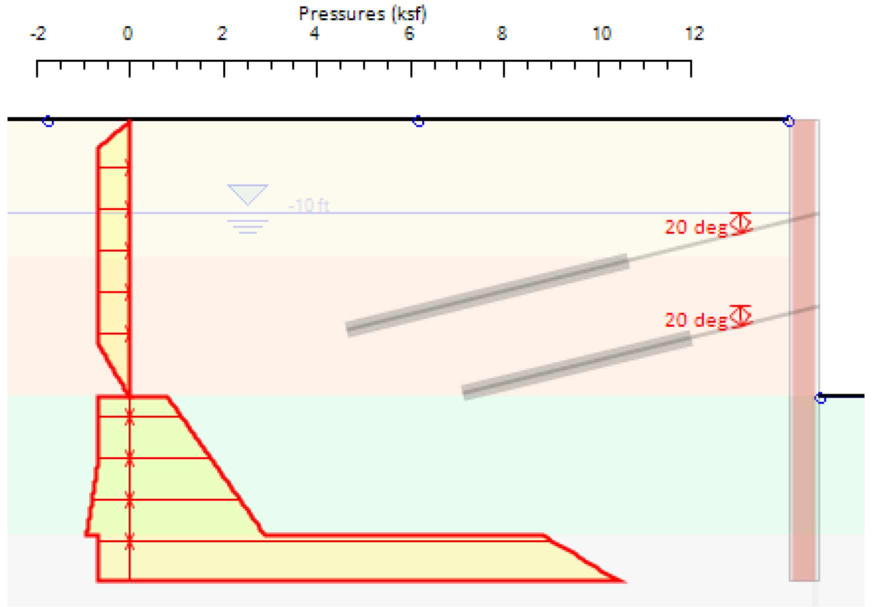
Two-Step Rectangular Pressures



WMATA Pressures



New York City DEP Pressures



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Water Pressure Methods

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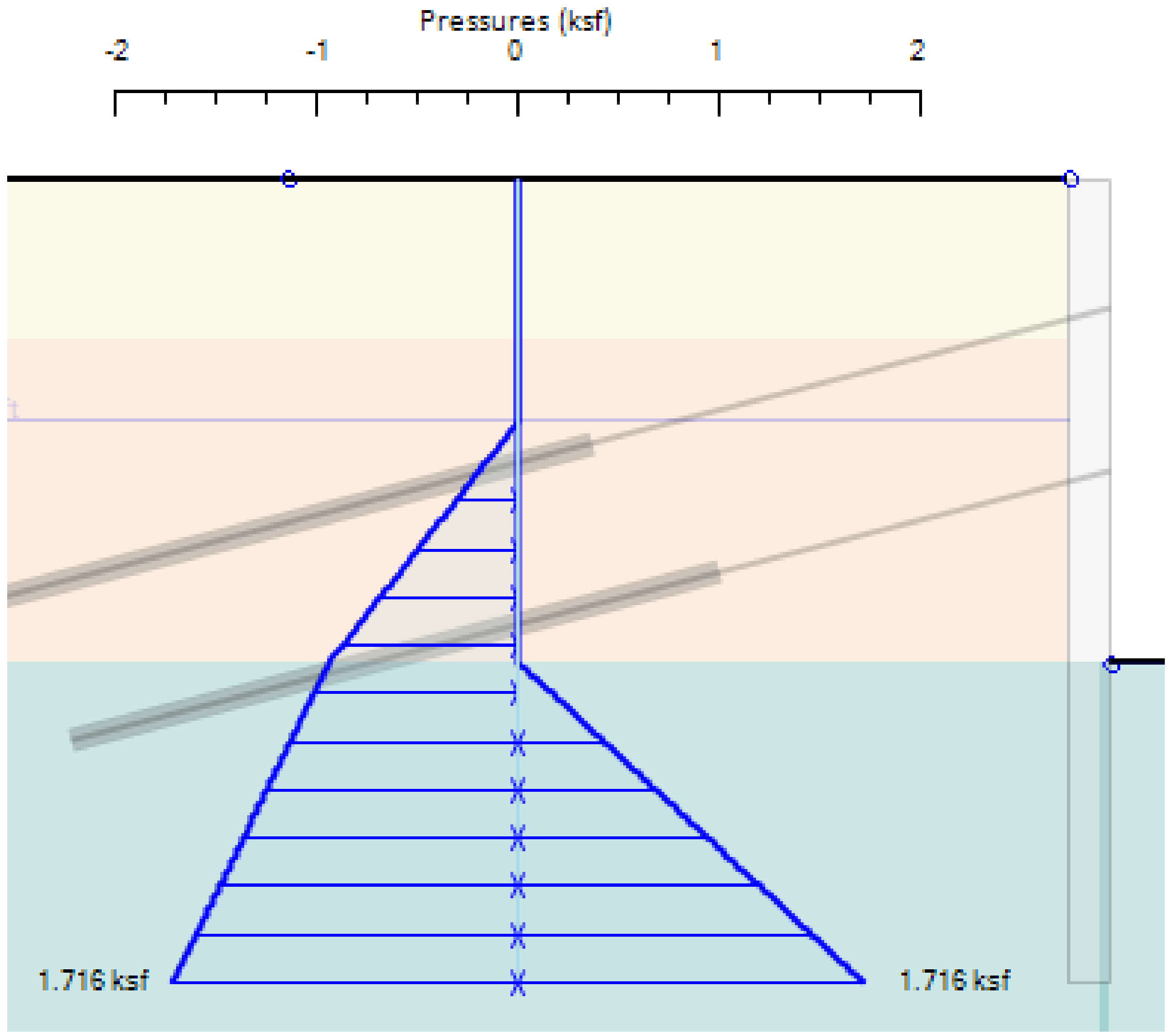
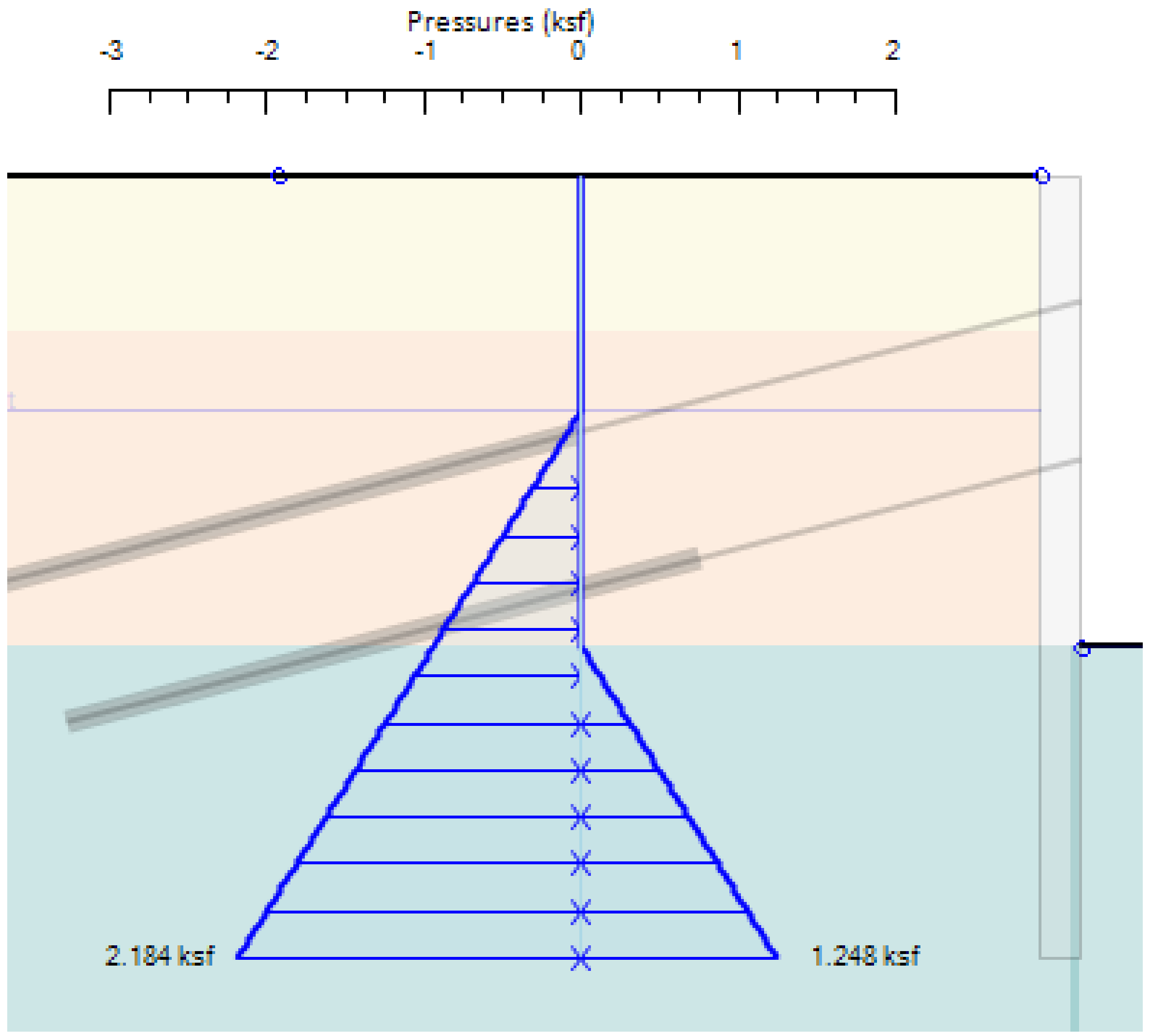
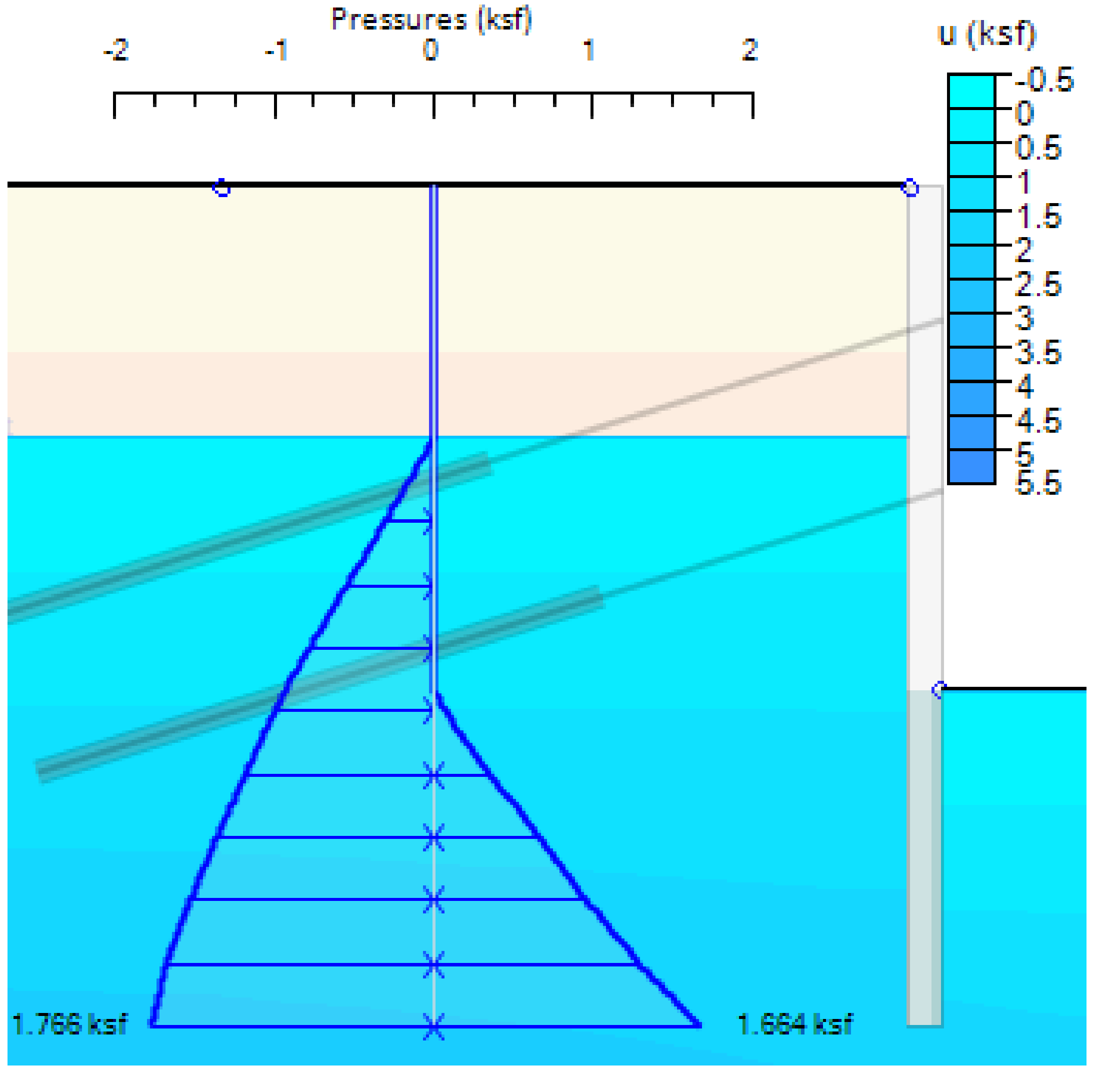
Simplified Flow



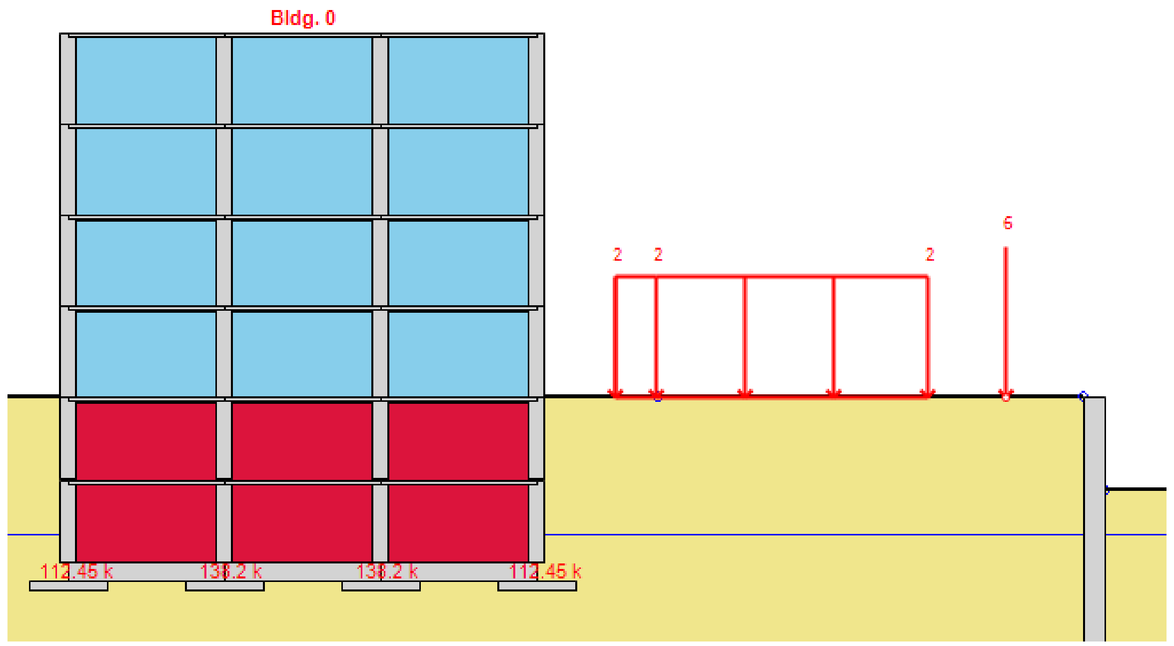
Hydrostatic

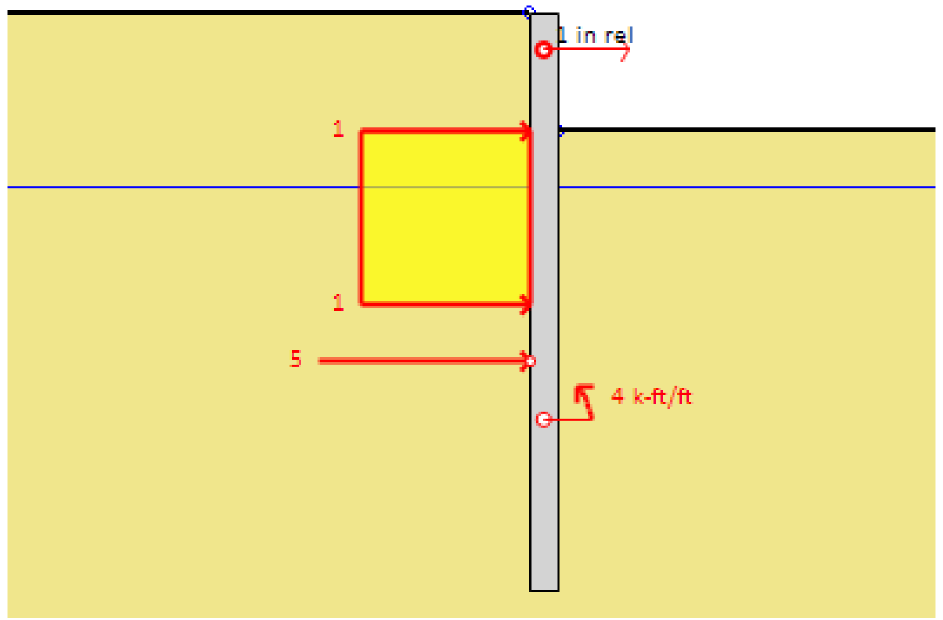


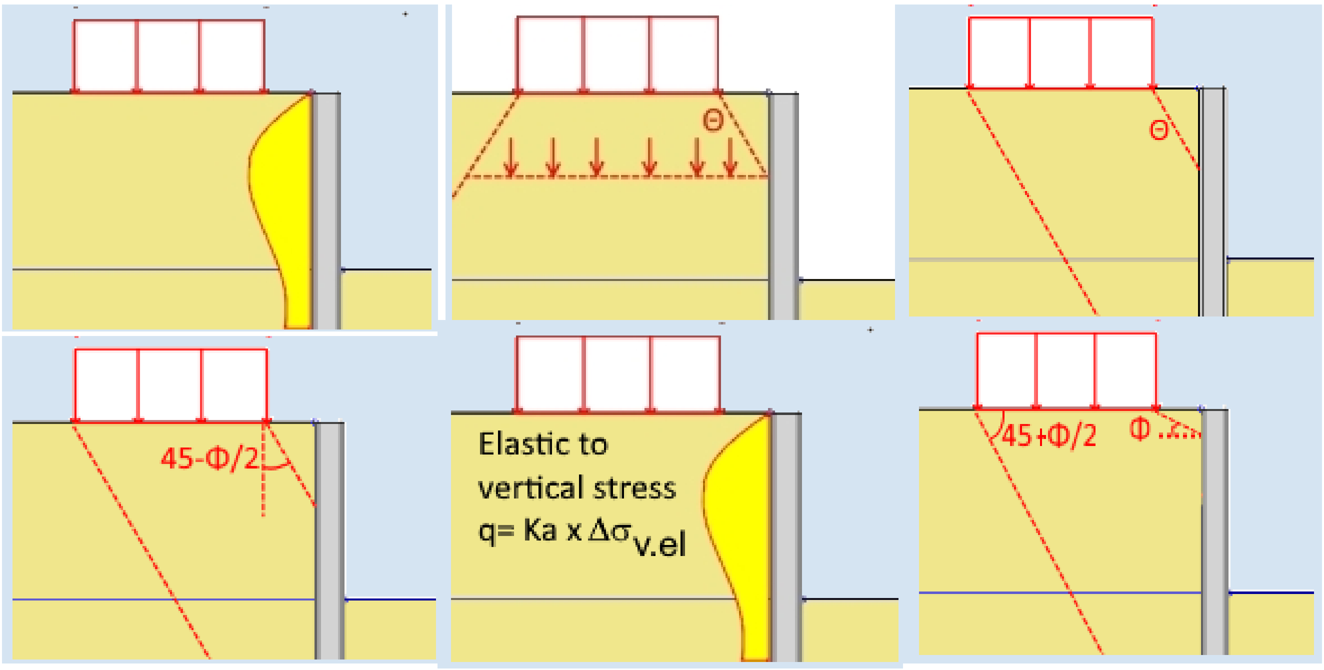
Full Flownet Analysis



External Loads: Types & Pressure Methods







Loads on ground surface:

- ✓ Strip surcharges
- ✓ Linear loads
- ✓ 3D loads (buildings, footings, 3D surface loads

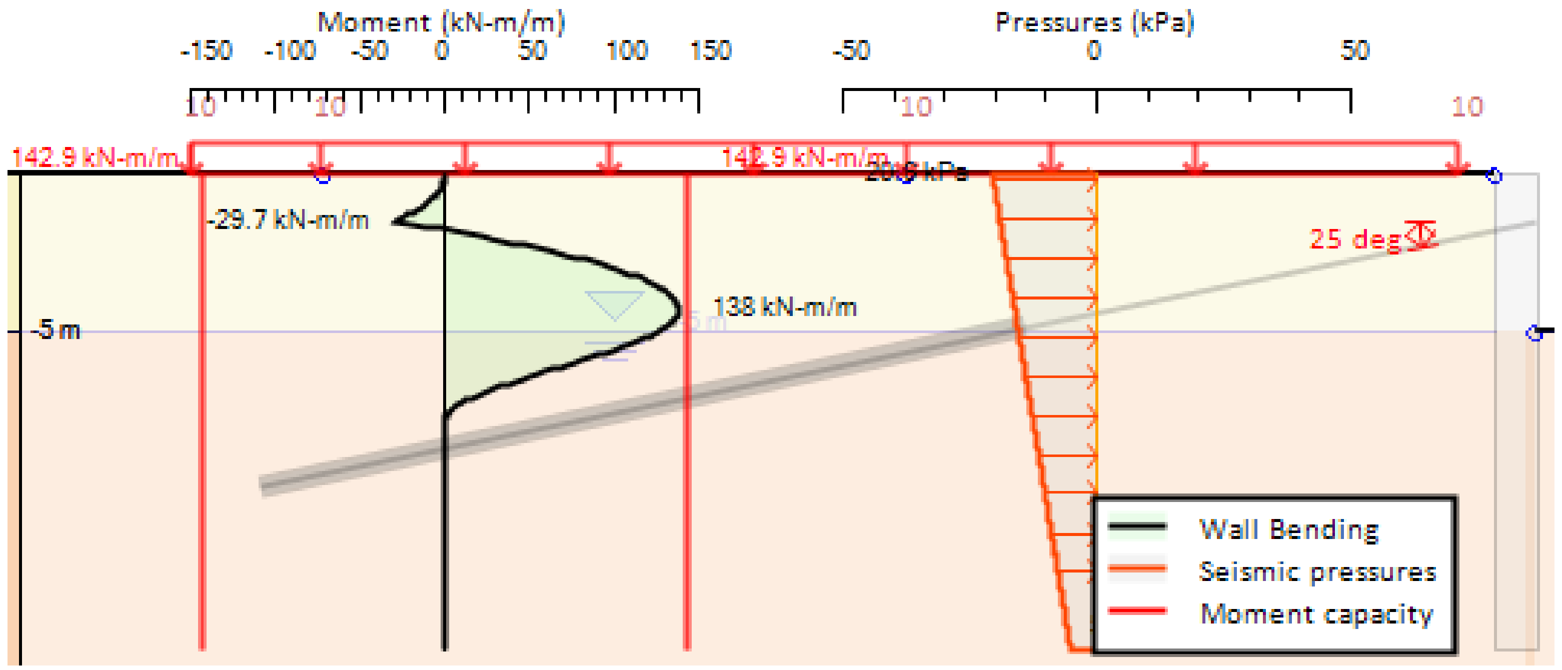
Loads on the wall:

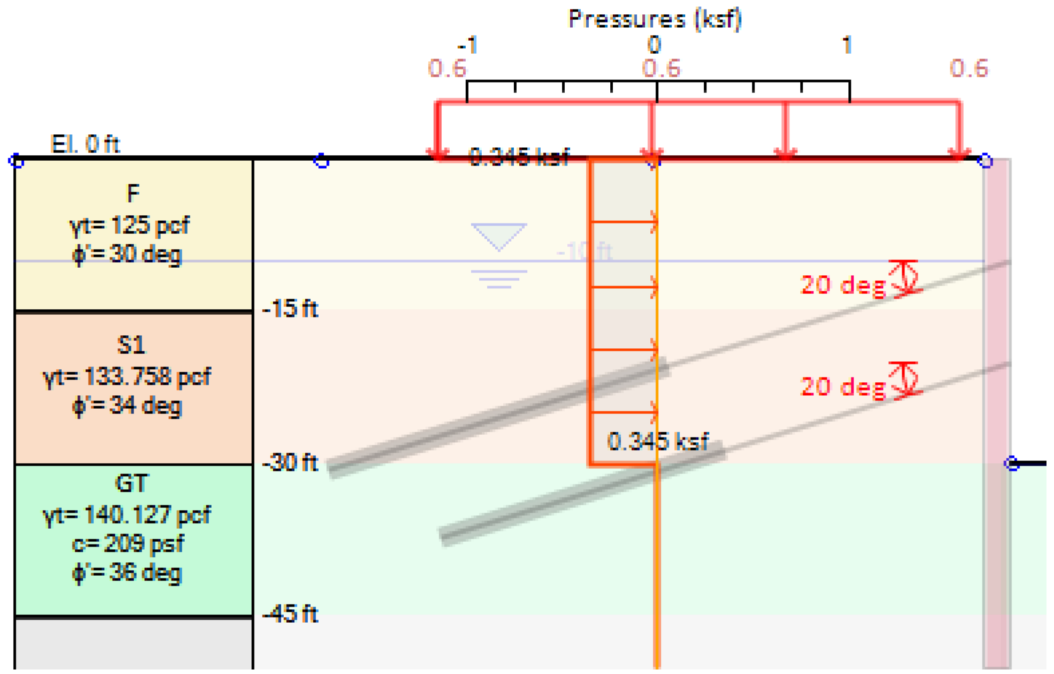
- ✓ Strip surcharges
- ✓ Linear loads
- ✓ External moments
- ✓ Prescribed displacements

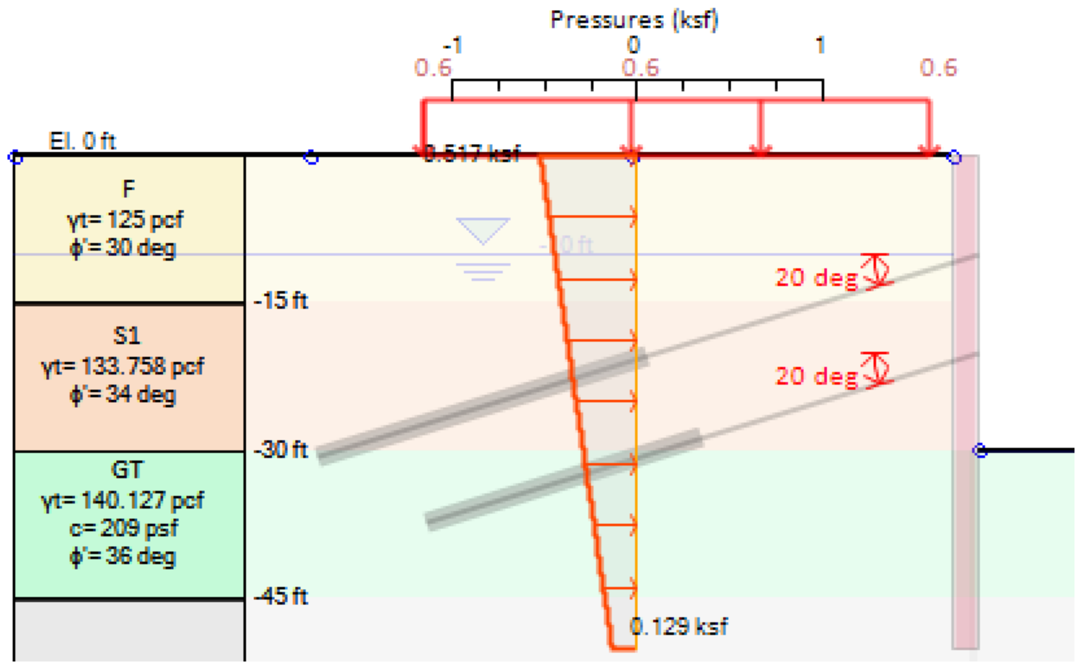
Load modeling options:

- ✓ Elasticity equations
- ✓ Two-way distribution angle
- ✓ One-way distribution angle
- ✓ One-way distribution angle from soil friction
- ✓ Elasticity to vertical stress x Ka (or Ko)
- ✓ CIRIA Special Pub 95 - 1993

Seismic Pressure Methods







Procedure in DeepEX

- ➢ Define Seismic Accelerations Ax and Az
- ➢ Select Seismic Pressures Calculation Method
- ➢ Select a Seismic Design Standard

Seismic Pressure Methods

- ✓ Semirigid
- ✓ Mononobe-Okabe (frictional soils)
- ✓ Wood Automatic
- ✓ Wood Manual

Semirigid Method

- ➢ Total Vertical Stress at Bottom of Wall x B
- ➢ B = 0.75 in DeepEX
- ➢ Rectangular Pressure Diagram

Mononobe-Okabe Method (Frictional Soils)

- ➢ Extension of the Coulomb Static Theory
- ➢ Accelerations added to a Coulomb Wedge
- ➢ Seed & Whitman (1970) Seismic Thrust Redistribution
- ➢ Inverse Trapezoid Pressure Diagram

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Slope Stability Analysis Options

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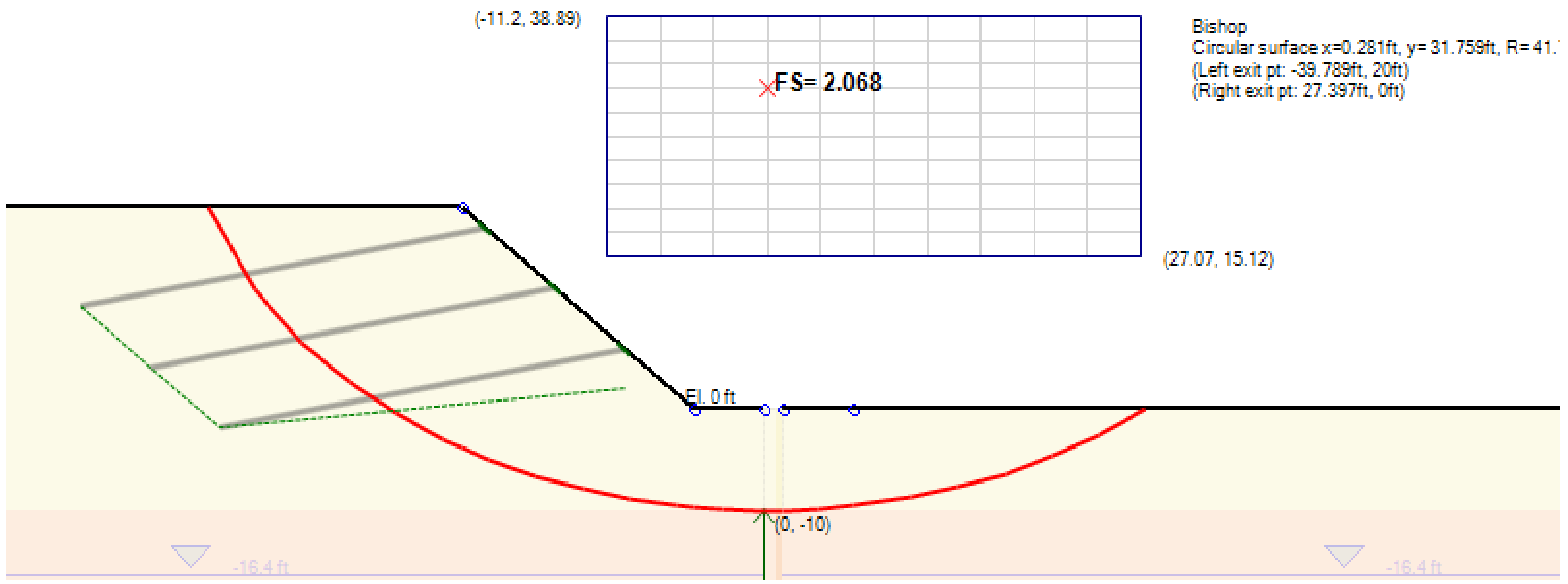
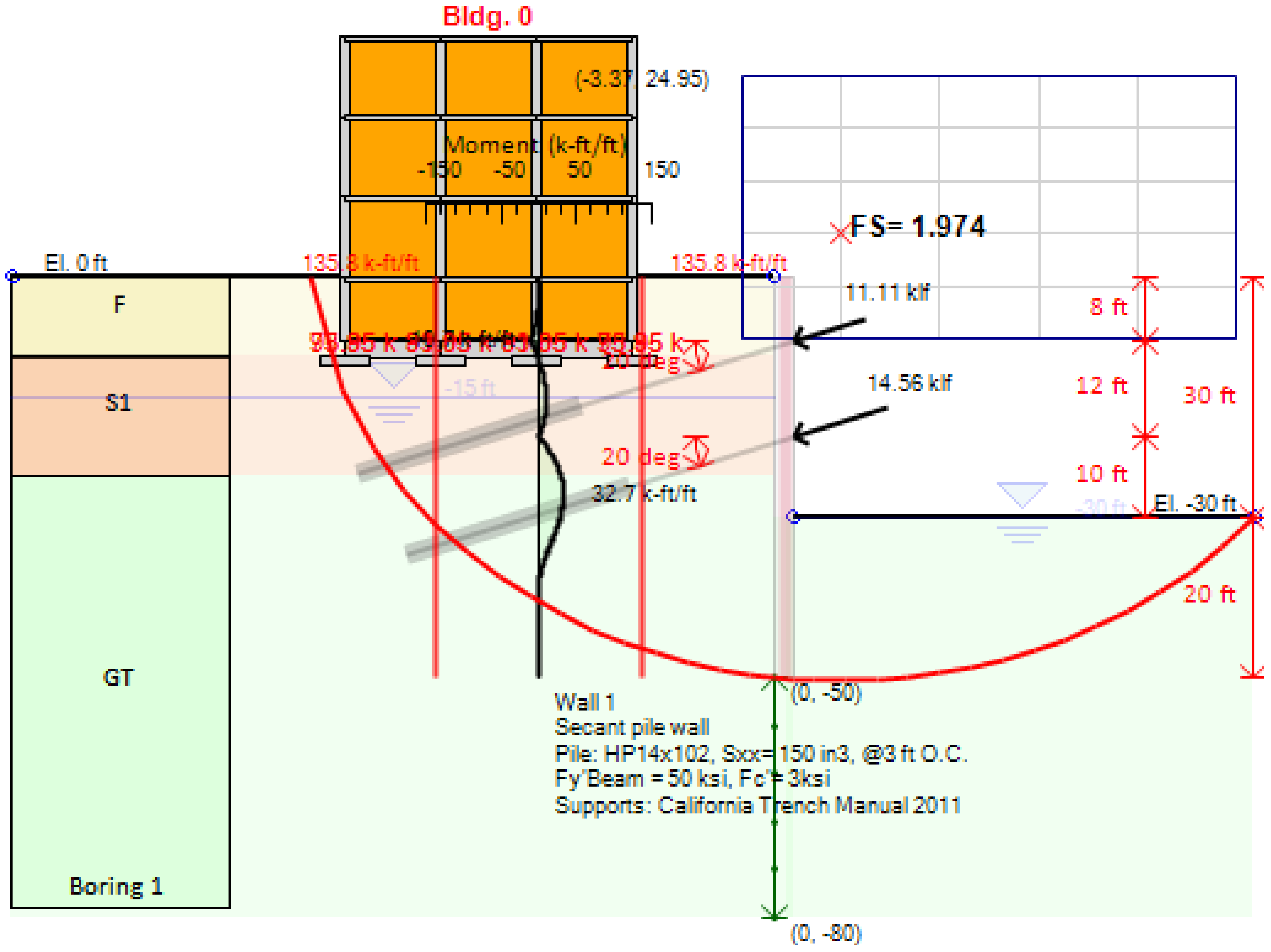
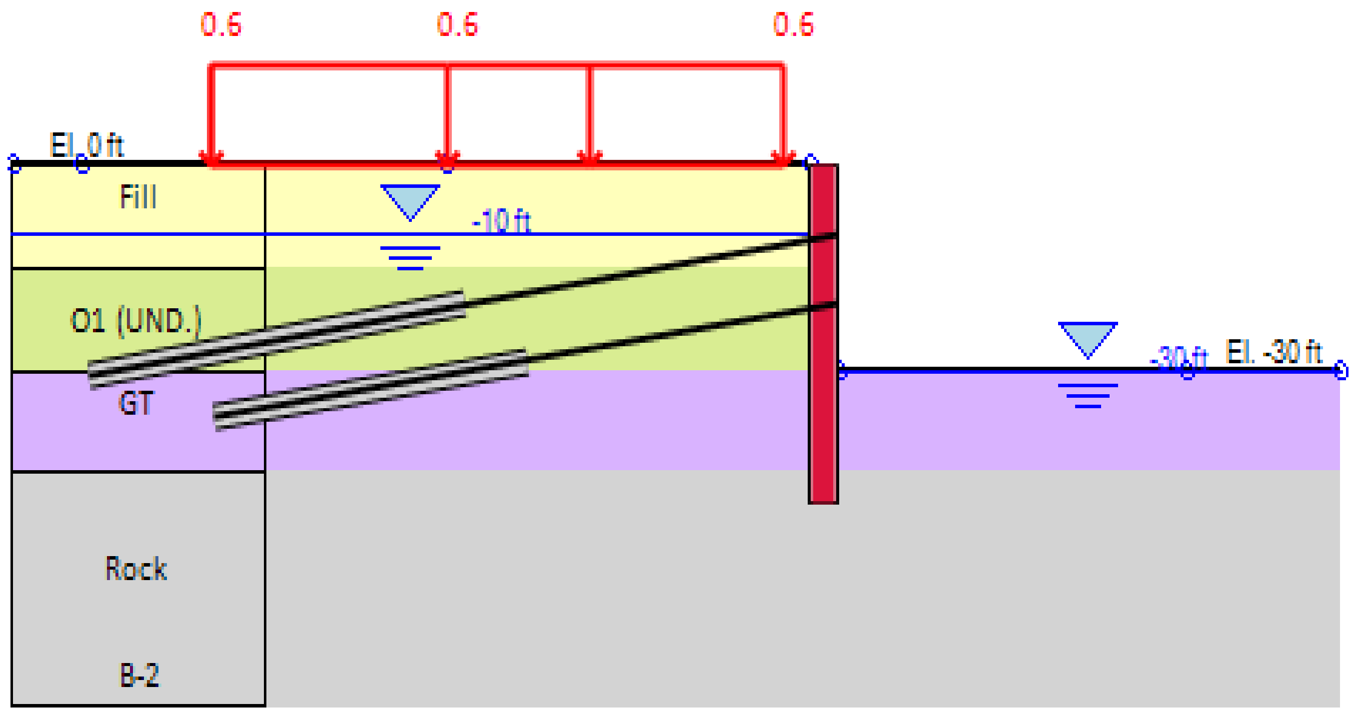
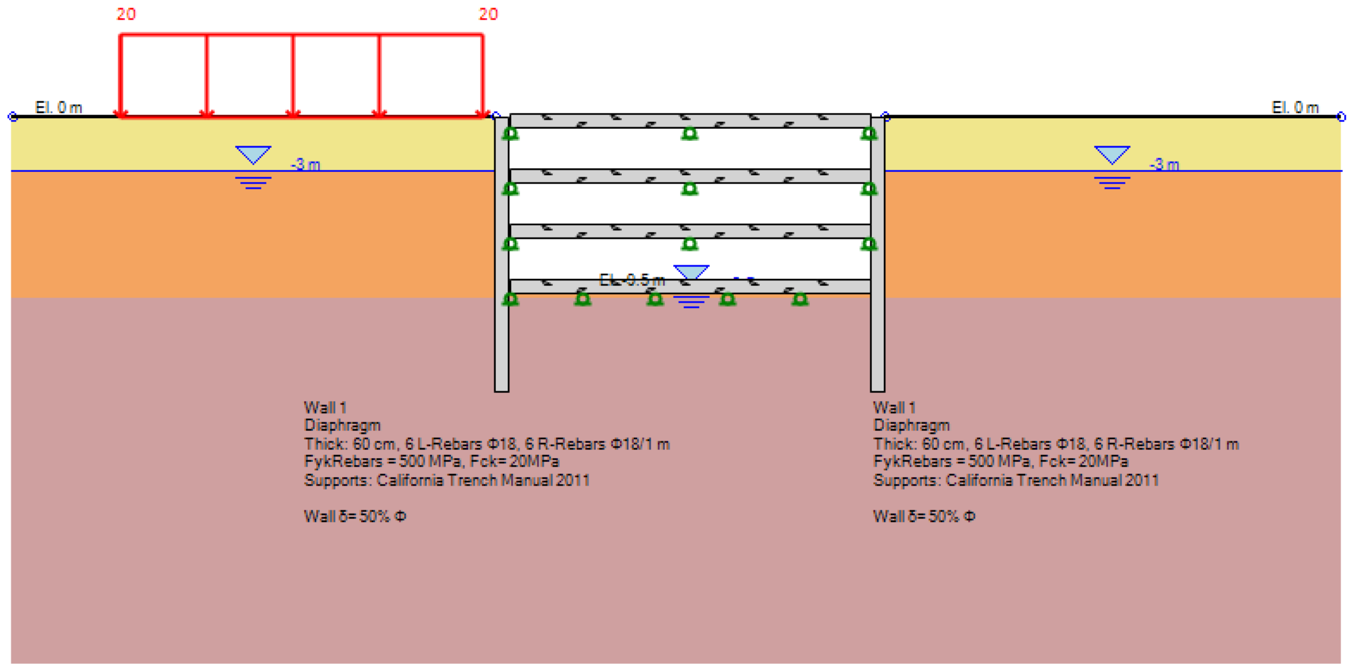


- ✓ Bishop Method
- ✓ Morgenstern Price Method (G.L.E.)
- ✓ Spencer Method
- ✓ Ordinary (Swedish) Method
- ✓ Automatic Slope Search Method
- ✓ Single Point Slope Center
- ✓ Rectangular Slope Center
- ✓ Define Radius Search Limits
- ✓ Clouterre Standards for Soil Nails



DeepEX - Shoring Design Examples





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Review Training Materials

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Example 1: Excavation with Tiebacks

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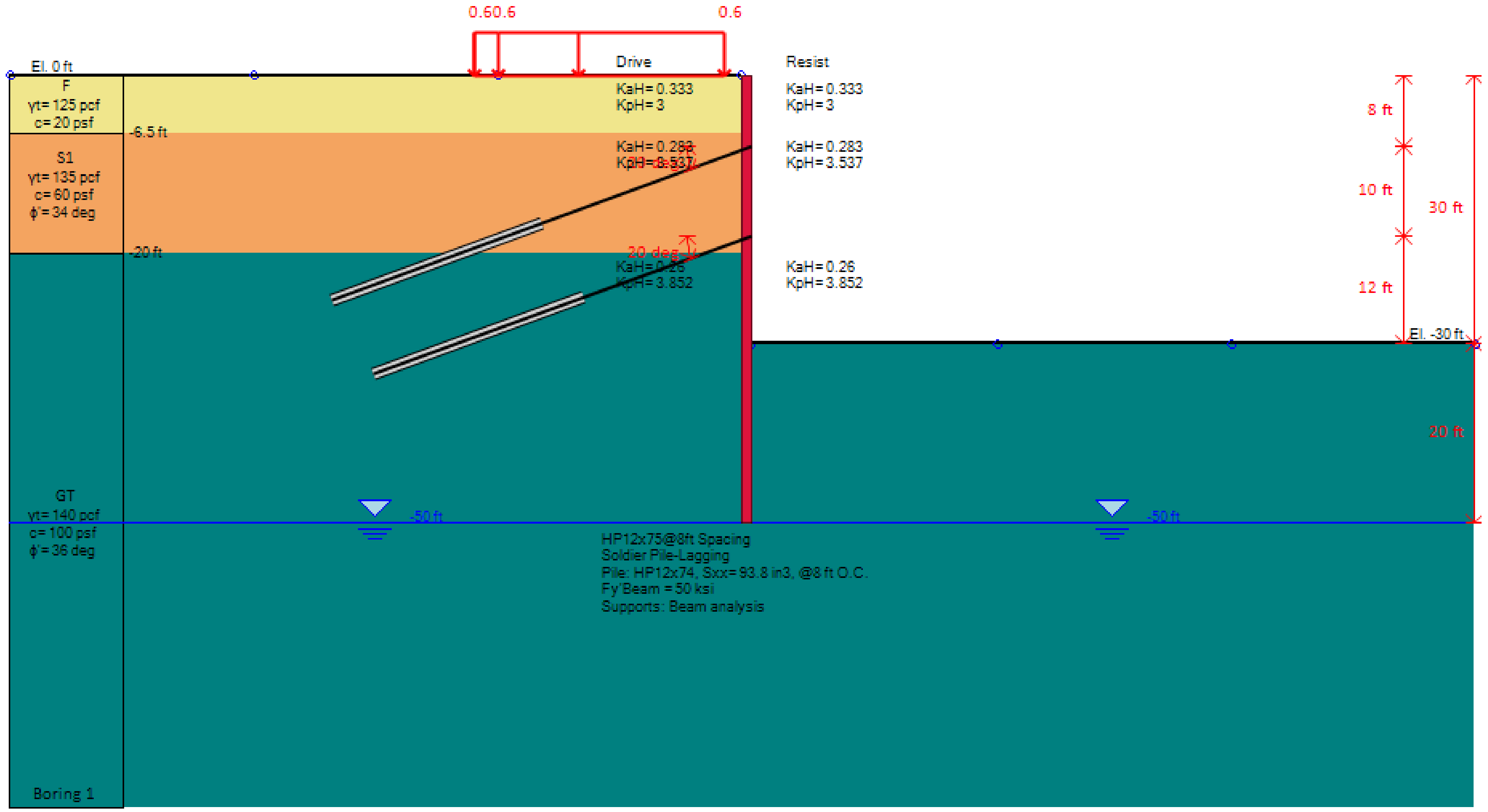

- ✓ Create Model Graphically (All Stages)
- ✓ Review Different Driving Pressure Diagrams (Peck, FHWA)
- ✓ Use Wall Friction
- ✓ Review and Evaluate the Results
- ✓ Perform Model Optimization (Embedment Depth, Wall Section, Anchors)
- ✓ Evaluate Drilled Soldier Piles in 2 ft Holes
- ✓ Examine Seismic Pressures
- ✓ Estimate Prestress for the Anchors
- ✓ Run Non-Linear Analysis

Soil Properties & Stratigraphy

Elev. (ft)	Soil (-)	γt (pcf)	γbulk (kN/m3)	C' (psf)	ϕ' (deg)	Eoed (ksf)	Eur (ksf)	m (-)
0	F - Sand	125	120	20	30	300	900	0.5
-6.5	S1 - Sand	135	125	60	34	520	1560	0.4
-20	GT - Till	140	130	100	36	600	1800	0.4

Water table at El: -50ft

Wall Section Properties

X-Coordinate	X = 0
Top Elevation	Z = 0
Wall Type	Driven Soldier Piles
Pile Section	HP12x75 (H Beams)
Pile Spacing	8ft
Lagging	2 in Timber Lagging

Support Properties (Tiebacks)

Support	First Row	Second Row
Elevation	Z = -8 ft	Z = -18 ft
Hor. Spacing	8 ft	8 ft
Section Type	4 x 0.6 in Strands	4 x 0.6 in Strands
Material	Strands 270 ksi	Strands 270 ksi
Free Length	25 ft	20 ft
Fixed Length	25 ft	25 ft

DeepEX Shoring Design Software

Example 2: Cofferdam

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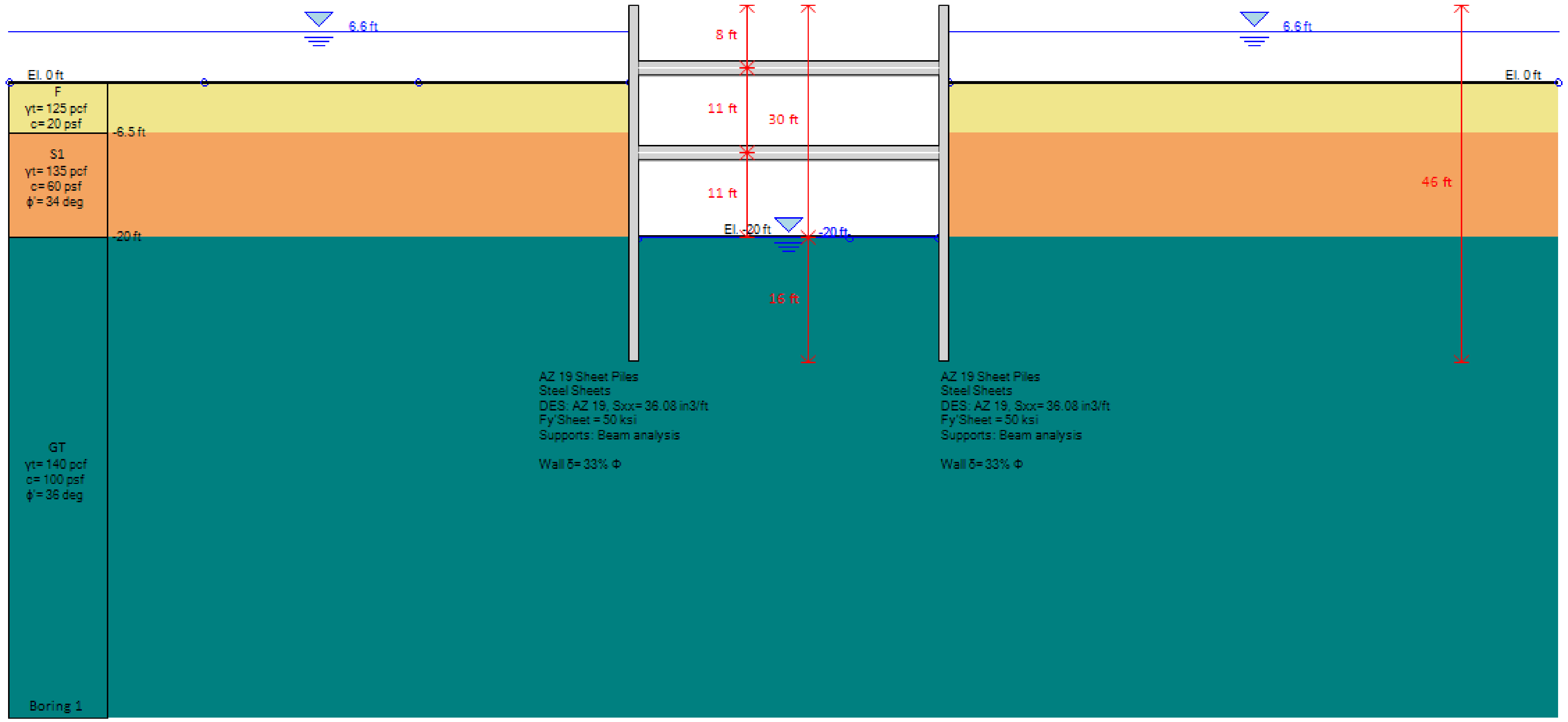

- ✓ Create Model Graphically (All Stages)
- ✓ Use Wall Friction
- ✓ Review and Evaluate the Results
- ✓ Perform Model Optimization (Embedment Depth, Wall Section, Struts)
- ✓ Examine Water Pressure Methods (Simplified Flow, Full Flownet)
- ✓ Run Non-Linear Analysis

Soil Properties & Stratigraphy

Elev. (ft)	Soil (-)	γt (pcf)	γbulk (kN/m3)	C' (psf)	ϕ' (deg)	Eoed (ksf)	Eur (ksf)	m (-)
0	F - Sand	125	120	20	30	300	900	0.5
-6.5	S1 - Sand	135	125	60	34	520	1560	0.4
-20	GT - Till	140	130	100	36	600	1800	0.4

Water table at El: 6.6ft

Wall Section Properties

X-Coordinate	X = 0	X = 40 ft
Top Elevation	Z = 10 ft	Z = 10 ft
Wall Type	Steel Sheet Piles	Steel Sheet Piles
Pile Section	AZ 19	AZ 19
Material	A50 Steel	A50 Steel

Support Properties (Struts)

Support	First Row	Second Row
Elevation	Z = 2 ft	Z = -9 ft
Hor. Spacing	10 ft	10 ft
Section Type	PP24x0.5 (Pipes)	PP24x0.5 (Pipes)
Material	A50 Steel	A50 Steel

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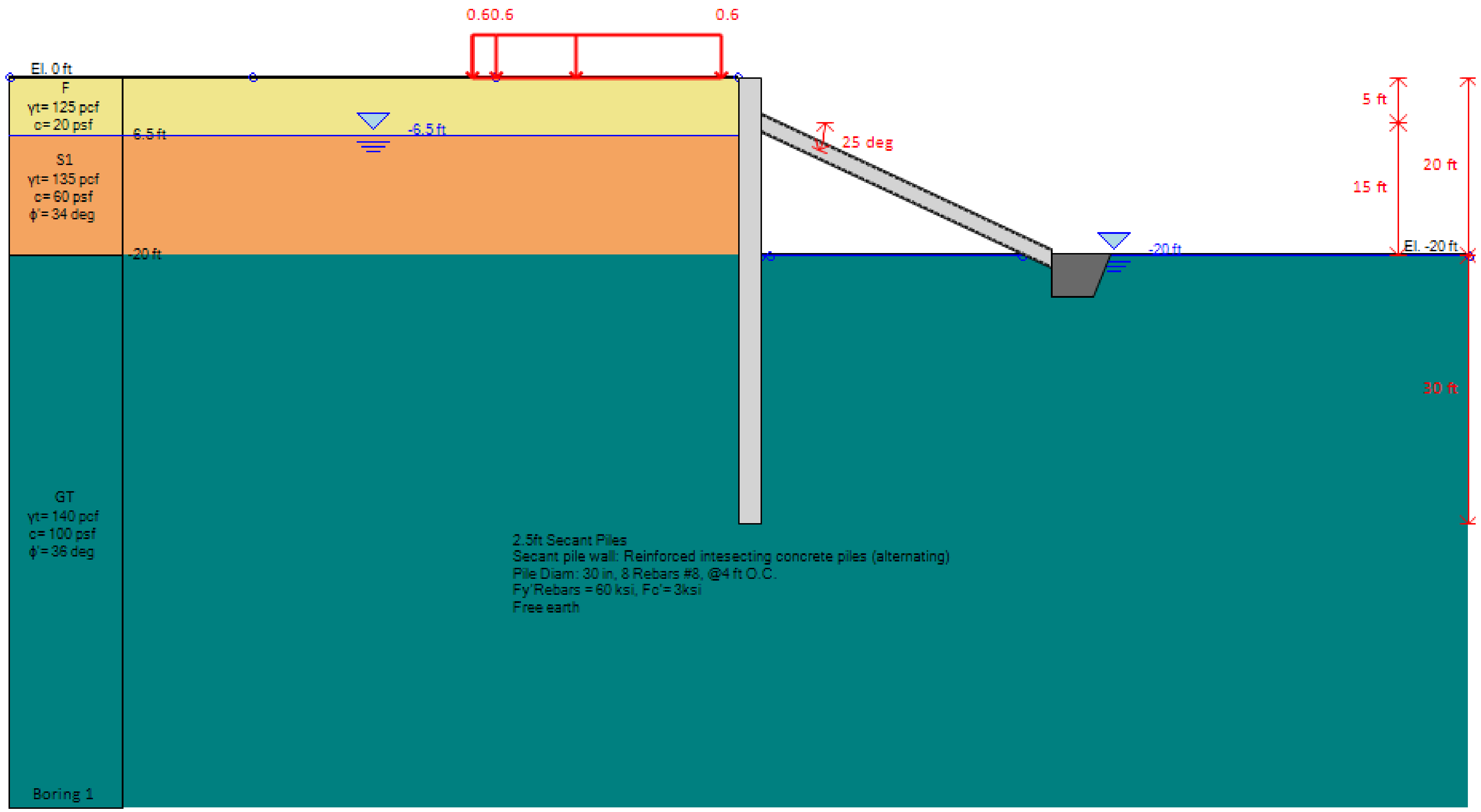
Example 3: Excavation with Rakers

www.deepexcavation.com



- ✓ Create Model Graphically (All Stages)
- ✓ Use Wall Friction
- ✓ Review and Evaluate the Results
- ✓ Run Non-Linear Analysis

Soil Properties & Stratigraphy

Elev. (ft)	Soil (-)	γt (pcf)	γbulk (kN/m3)	C' (psf)	ϕ' (deg)	Eoed (ksf)	Eur (ksf)	m (-)
0	F - Sand	125	120	20	30	300	900	0.5
-6.5	S1 - Sand	135	125	60	34	520	1560	0.4
-20	GT - Till	140	130	100	36	600	1800	0.4

Water table at El: -6.5ft

Wall Section Properties

X-Coordinate	X = 0
Top Elevation	Z = 0
Wall Type	Secant Piles
Pile Section	2.5ft Diam. Concrete Piles
Pile Spacing	4 ft
Reinforcement	8#8 Bars, #4 Shear Reinf.

Support Properties (Raker)

Support	First Row
Elevation	Z = 5 ft
Angle from Hor.	25 deg
Hor. Spacing	10 ft
Section Type	PP24x0.5 (Pipes)
Material	A50 Steel

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Example 4: Excavation with Struts

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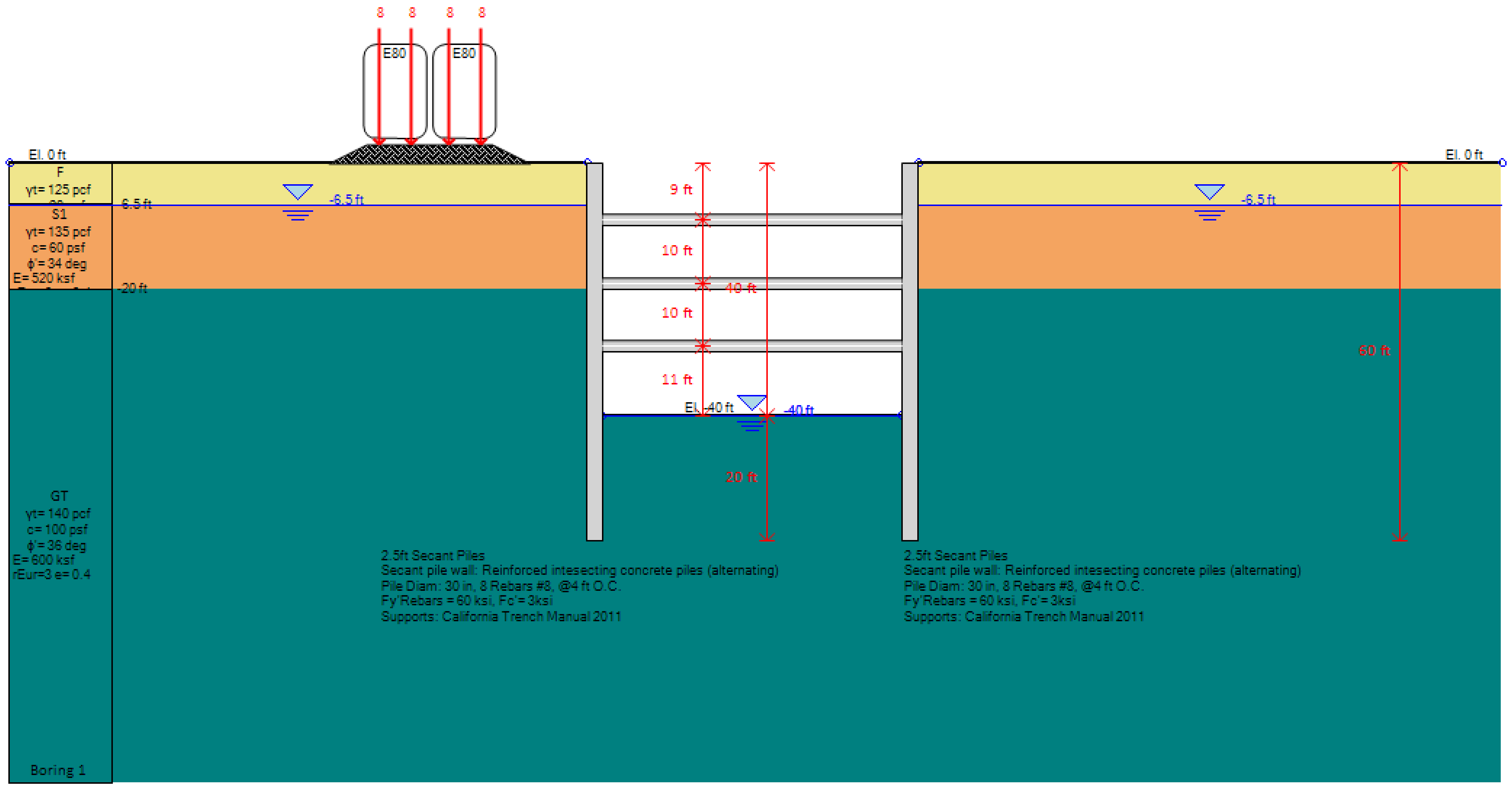

- ✓ Create Model with the Model Wizard (All Stages)
- ✓ Add Train Loads
- ✓ Review and Evaluate the Results
- ✓ Run Non-Linear Analysis
- ✓ Add Basement Walls and Base Slab - Remove Struts

Soil Properties & Stratigraphy

Elev. (ft)	Soil (-)	γt (pcf)	γbulk (kN/m3)	C' (psf)	ϕ' (deg)	Eoed (ksf)	Eur (ksf)	m (-)
0	F - Sand	125	120	20	30	300	900	0.5
-6.5	S1 - Sand	135	125	60	34	520	1560	0.4
-20	GT - Till	140	130	100	36	600	1800	0.4

Water table at El: -6.5ft

Wall Section Properties

X-Coordinate	X = 0	X = 50 ft
Top Elevation	Z = 0	Z = 0
Wall Type	Secant Piles	Secant Piles
Pile Section	2.5ft Diam. Concrete Piles	2.5ft Diam. Concrete Piles
Pile Spacing	4 ft	4 ft
Reinforcement	8#8 Bars, #4 Shear Reinf.	8#8 Bars, #4 Shear Reinf.

Support Properties (Struts)

Support	First Row	Second Row	Third Row
Elevation	Z = -9 ft	Z = -19 ft	Z = -29 ft
Hor. Spacing	20 ft	20 ft	20 ft
Section Type	PP24x0.5 (Pipes)	PP24x0.5 (Pipes)	PP24x0.5 (Pipes)
Material	A50 Steel	A50 Steel	A50 Steel

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Example 4: Excavation with Struts

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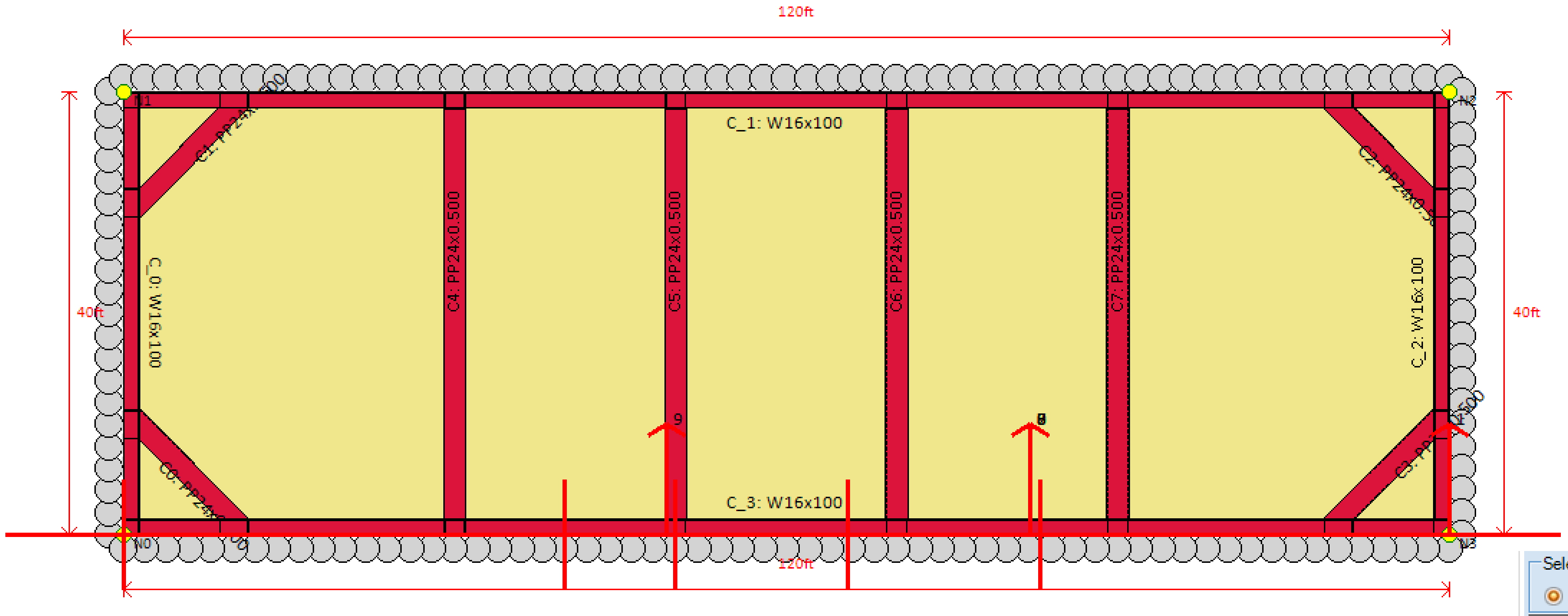
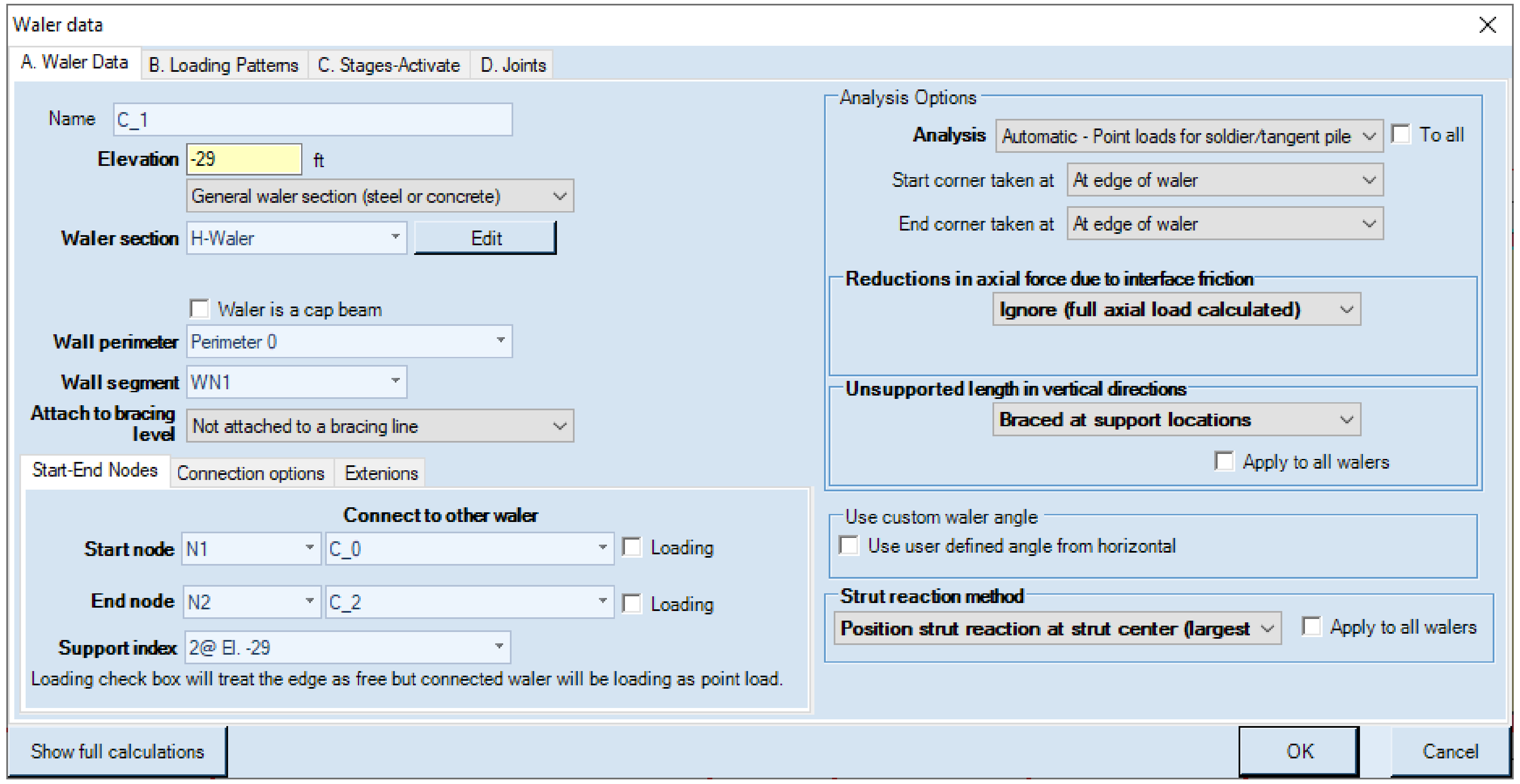
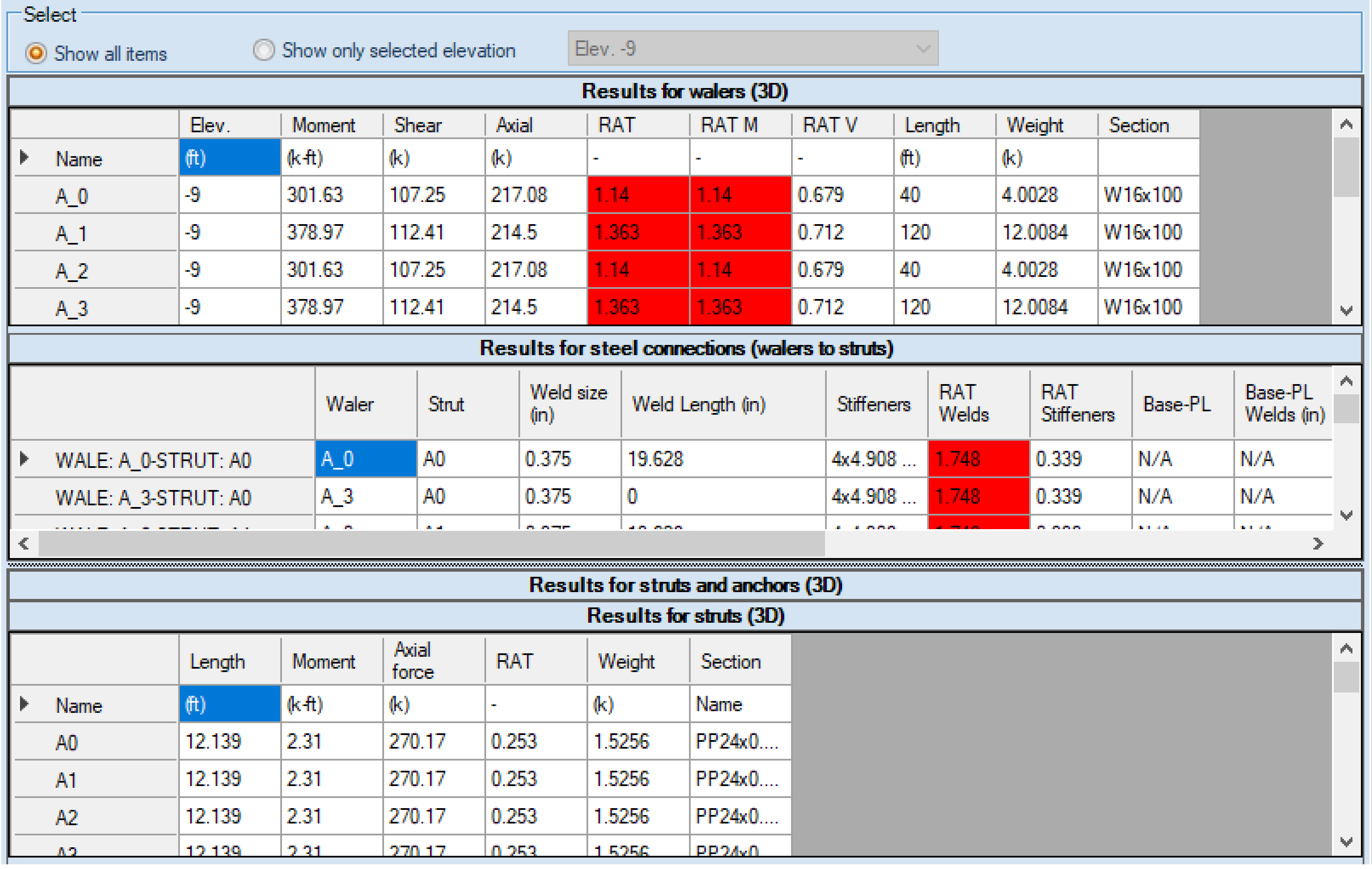


- ✓ Create the 3D Frame Model (120ft x 40ft Excavation)
- ✓ Review Structural Sections for Struts and Walers
- ✓ Review Locations of Struts for each Bracing Level
- ✓ Analyze the 3D Model and Review Results
- ✓ Review Steel Connection Options
- ✓ Export the 3D Model Hologram





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Example 5: Top-Down Excavation (Slabs)

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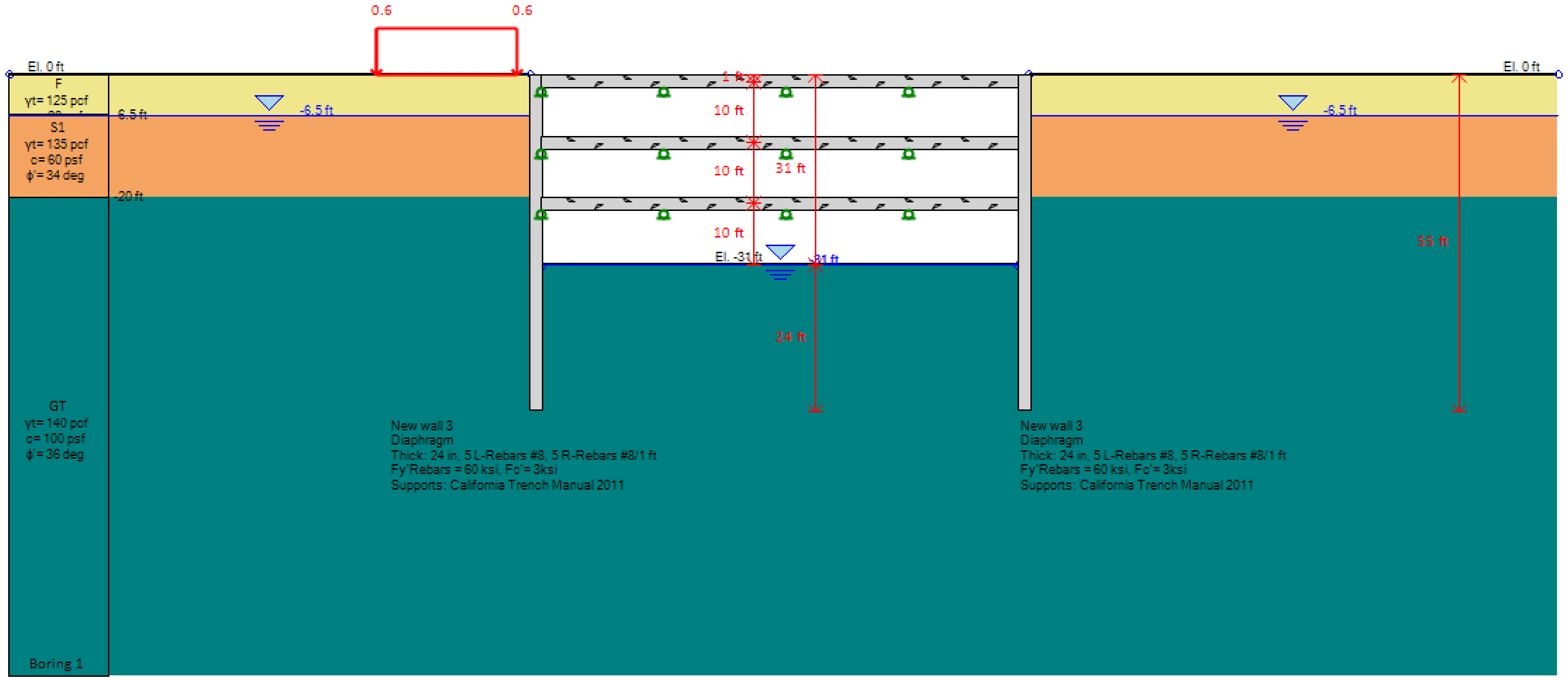

Soil Properties & Stratigraphy

Elev. (ft)	Soil (-)	γt (pcf)	γbulk (kN/m3)	C' (psf)	ϕ' (deg)	Eoed (ksf)	Eur (ksf)	m (-)
0	F - Sand	125	120	20	30	300	900	0.5
-6.5	S1 - Sand	135	125	60	34	520	1560	0.4
-20	GT - Till	140	130	100	36	600	1800	0.4

Water table at El: -6.5ft

Wall Section Properties

X-Coordinate	X = 0	X = 80 ft
Top Elevation	Z = 0	Z = 0
Wall Section	2ft Thick Concrete Diaphragm	2ft Thick Concrete Diaphragm
Long. Reinf.	3 #8 Bars /ft of wall (left and right)	3 #8 Bars /ft of wall (left and right)
Shear Reinf	#4 Bars @ 6in Spacing	#4 Bars @ 6in Spacing

- ✓ Create Model with the Model Wizard (All Stages)
- ✓ Review and Evaluate the Results
- ✓ Run NL Analysis - Adjust Slab Stiffness (shrinkage)

Support Properties (Slabs)

Support	First Row	Second Row	Third Row
Elevation	Z = -1 ft	Z = -10 ft	Z = -21 ft
Slab Thickness	2 ft	2 ft	2 ft

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Example 6: Deadman Wall

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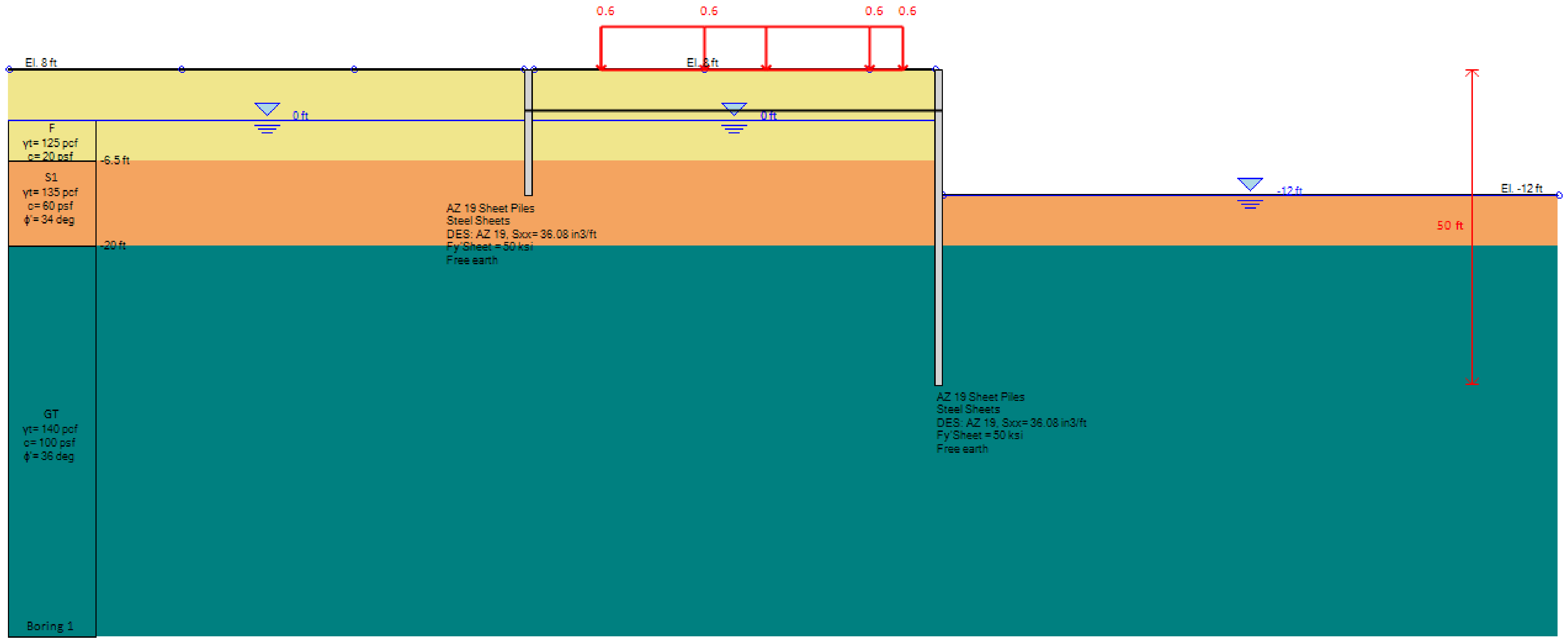

- ✓ Create Model Graphically (All Stages)
- ✓ Use Wall Friction
- ✓ Review and Evaluate the Results
- ✓ Examine the Interaction between the Walls
- ✓ Impact Load Adjustment Factor

Soil Properties & Stratigraphy

Elev. (ft)	Soil (-)	γt (pcf)	γbulk (kN/m3)	C' (psf)	ϕ' (deg)	Eoed (ksf)	Eur (ksf)	m (-)
0	F - Sand	125	120	20	30	300	900	0.5
-6.5	S1 - Sand	135	125	60	34	520	1560	0.4
-20	GT - Till	140	130	100	36	600	1800	0.4

Water table at El: 0

Wall Section Properties

X-Coordinate	X = 0	X = 12 m
Top Elevation	Z = 8 ft	Z = 8 ft
Wall Type	Steel Sheet Piles	Steel Sheet Piles
Pile Section	AZ 19	AZ 19
Material	A50 Steel	A50 Steel

Support Properties (Tierods)

Elevation	Z = 1.5 ft
Hor. Spacing	6 ft
Section Type	1 Rebar #14
Material	Grade 75

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Example 7: Slope Stability Analysis

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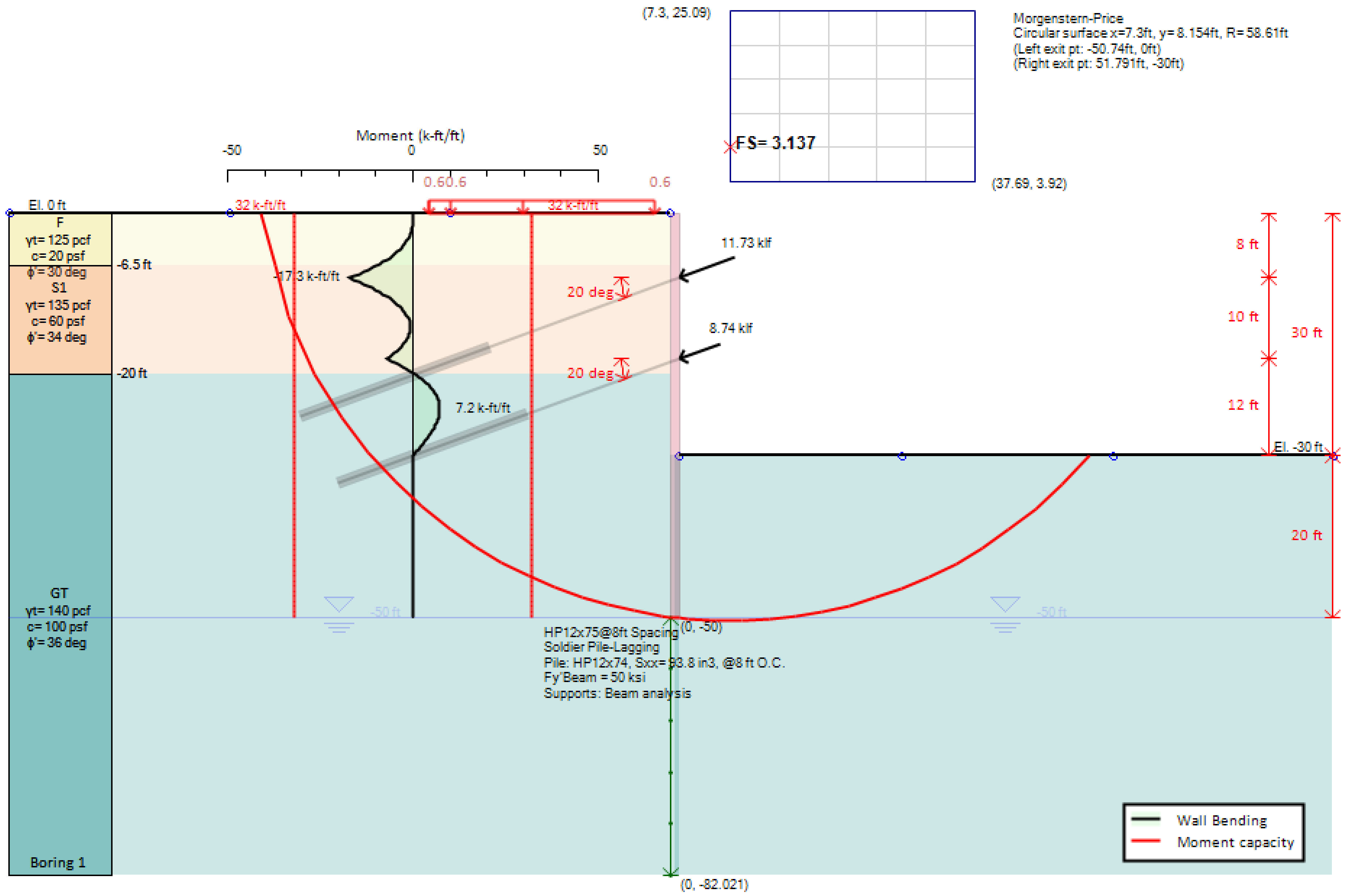


Elev. (ft)	Soil (-)	γt (pcf)	γbulk (kN/m3)	C' (psf)	ϕ' (deg)	Eoed (ksf)	Eur (ksf)	m (-)
0	F - Sand	125	120	20	30	300	900	0.5
-6.5	S1 - Sand	135	125	60	34	520	1560	0.4
-20	GT - Till	140	130	100	36	600	1800	0.4

Water table at El: -50ft

Wall Section Properties

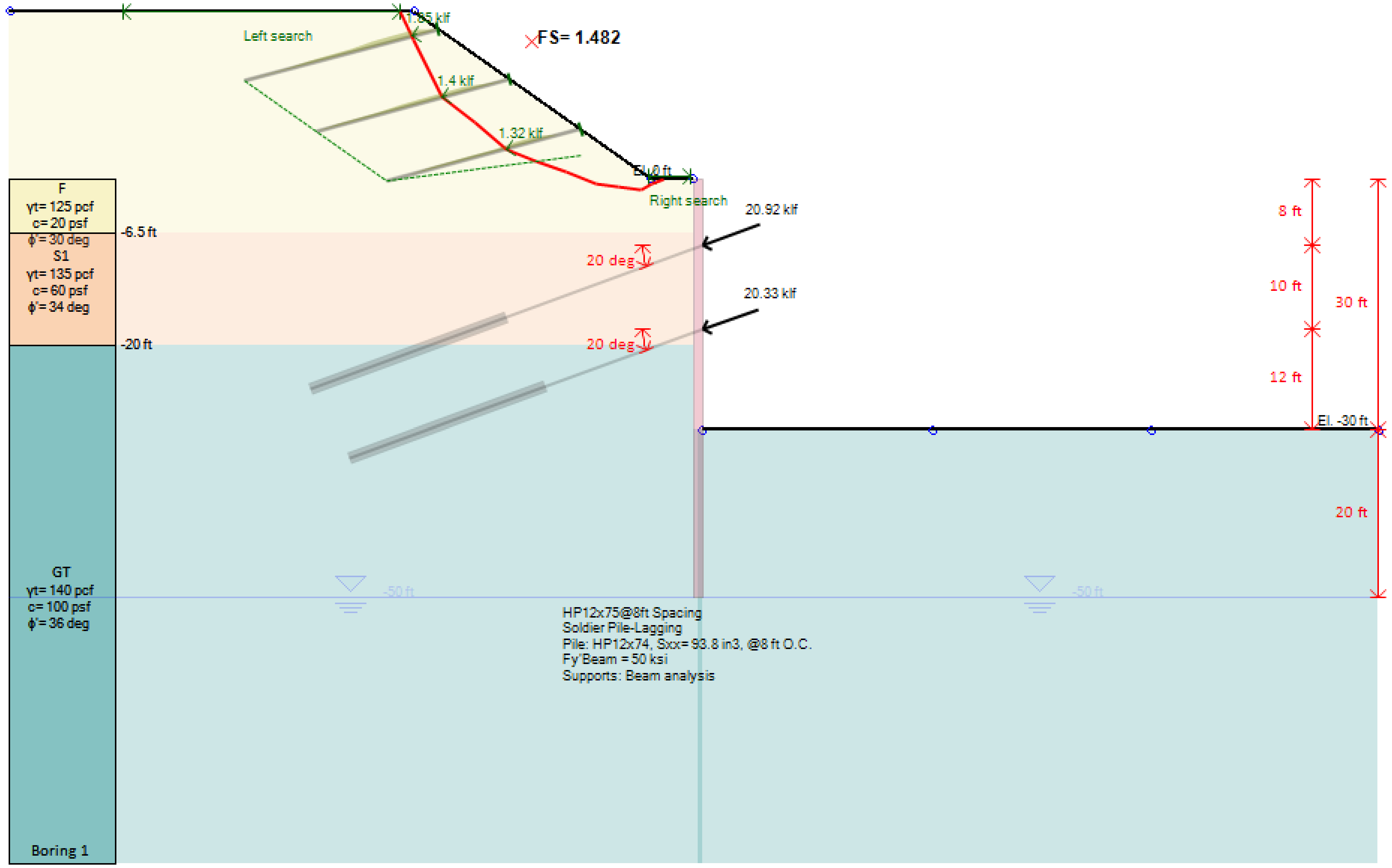
X-Coordinate	X = 0
Top Elevation	Z = 0
Wall Type	Driven Soldier Piles
Pile Section	HP12x75 (H Beams)
Pile Spacing	8ft
Lagging	2 in Timber Lagging

Support Properties (Tiebacks)

Support	First Row	Second Row
Elevation	Z = -8 ft	Z = -18 ft
Hor. Spacing	8 ft	8 ft
Section Type	4 x 0.6 in Strands	4 x 0.6 in Strands
Material	Strands 270 ksi	Strands 270 ksi
Free Length	25 ft	20 ft
Fixed Length	25 ft	25 ft

- ✓ Copy the Anchored Wall Model (Example 1)
- ✓ Slope Stability Analysis (Morgenstern-Price, Circular Slope Surface Options)

Example 8: Soil Nails - Slope Stability Analysis



- ✓ Copy the Anchored Wall Model (Example 1)
- ✓ Create a Bench and Add Soil Nails
- ✓ Slope Stability Analysis (Morgenstern-Price, Automatic Slope Surface Options)

Elev. (ft)	Soil (-)	γt (pcf)	γbulk (kN/m3)	C' (psf)	ϕ' (deg)	Eoed (ksf)	Eur (ksf)	m (-)
0	F - Sand	125	120	20	30	300	900	0.5
-6.5	S1 - Sand	135	125	60	34	520	1560	0.4
-20	GT - Till	140	130	100	36	600	1800	0.4

Water table at El: -50ft

Wall Section Properties

X-Coordinate	X = 0
Top Elevation	Z = 0
Wall Type	Driven Soldier Piles
Pile Section	HP12x75 (H Beams)
Pile Spacing	8ft
Lagging	2 in Timber Lagging

Support Properties (Tiebacks)

Support	First Row	Second Row
Elevation	Z = -8 ft	Z = -18 ft
Hor. Spacing	8 ft	8 ft
Section Type	4 x 0.6 in Strands	4 x 0.6 in Strands
Material	Strands 270 ksi	Strands 270 ksi
Free Length	25 ft	20 ft
Fixed Length	25 ft	25 ft

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Example 9: Circular Shaft

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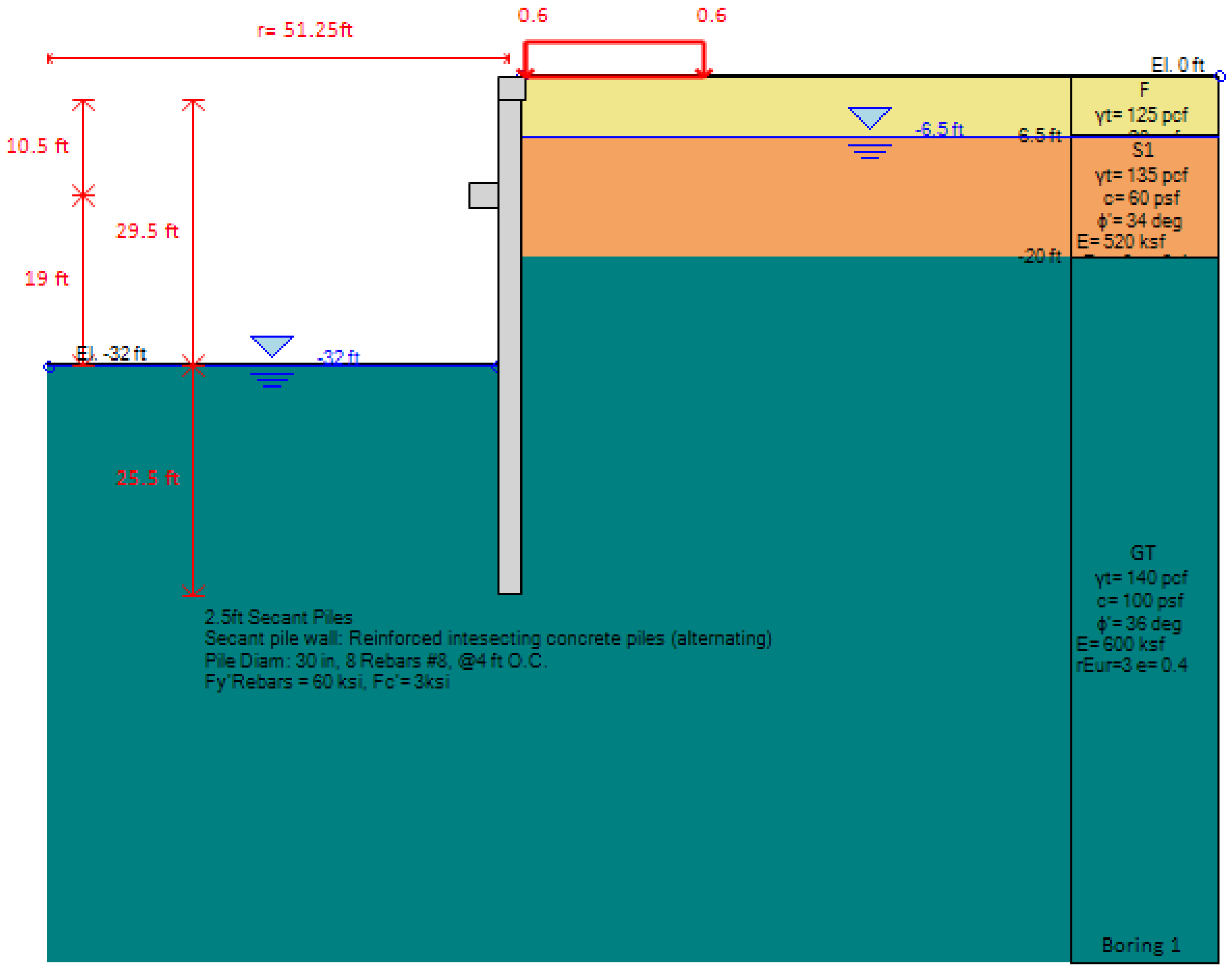

- ✓ Create Model with the Model Wizard (All Stages)
- ✓ Review and Evaluate the Results

Soil Properties & Stratigraphy

Elev. (ft)	Soil (-)	γt (pcf)	γbulk (kN/m3)	C' (psf)	ϕ' (deg)	Eoed (ksf)	Eur (ksf)	m (-)
0	F - Sand	125	120	20	30	300	900	0.5
-6.5	S1 - Sand	135	125	60	34	520	1560	0.4
-20	GT - Till	140	130	100	36	600	1800	0.4

Water table at El: -6.5ft

Wall Section Properties

X-Coordinate	X = 0
Top Elevation	Z = 0
Wall Type	Secant Piles
Pile Section	2.5 ft Diam. Concrete Piles
Pile Spacing	4 ft
Reinforcement	8#8 Bars, #4 Shear Reinf.

Support Properties

Support	Cap Beam	Ring Beam
Elevation	Z = -1.5 ft	Z = -13 ft
Section Type	3ft x 3 ft Concrete Beam	36 in x 42 in Concrete Beam

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Example 10: Box Excavation

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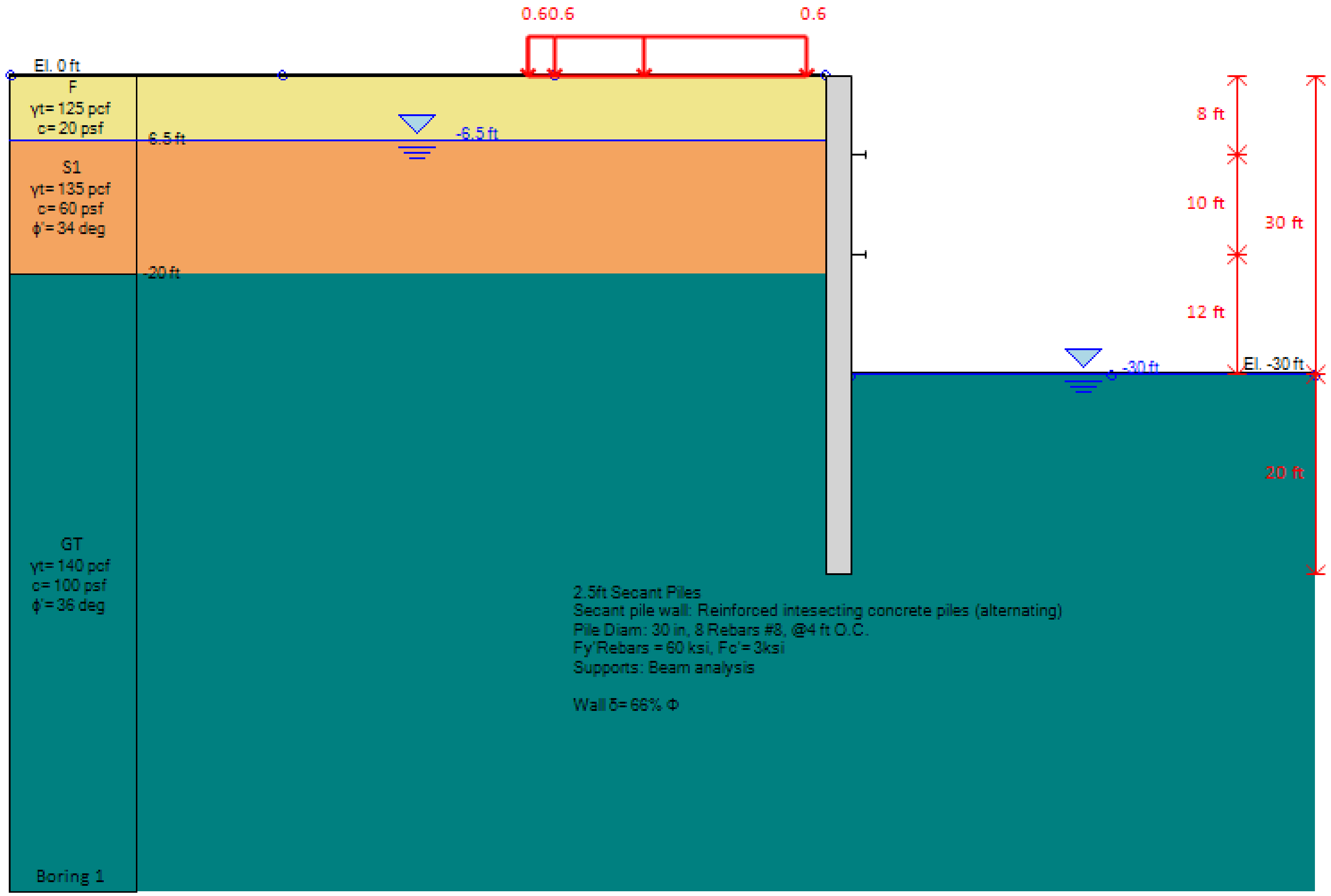


- ✓ Create Model Graphically (All Stages)
- ✓ Review and Evaluate the Results

Soil Properties & Stratigraphy

Elev. (ft)	Soil (-)	γt (pcf)	γbulk (kN/m3)	C' (psf)	ϕ' (deg)	Eoed (ksf)	Eur (ksf)	m (-)
0	F - Sand	125	120	20	30	300	900	0.5
-6.5	S1 - Sand	135	125	60	34	520	1560	0.4
-20	GT - Till	140	130	100	36	600	1800	0.4

Water table at El: -6.5ft

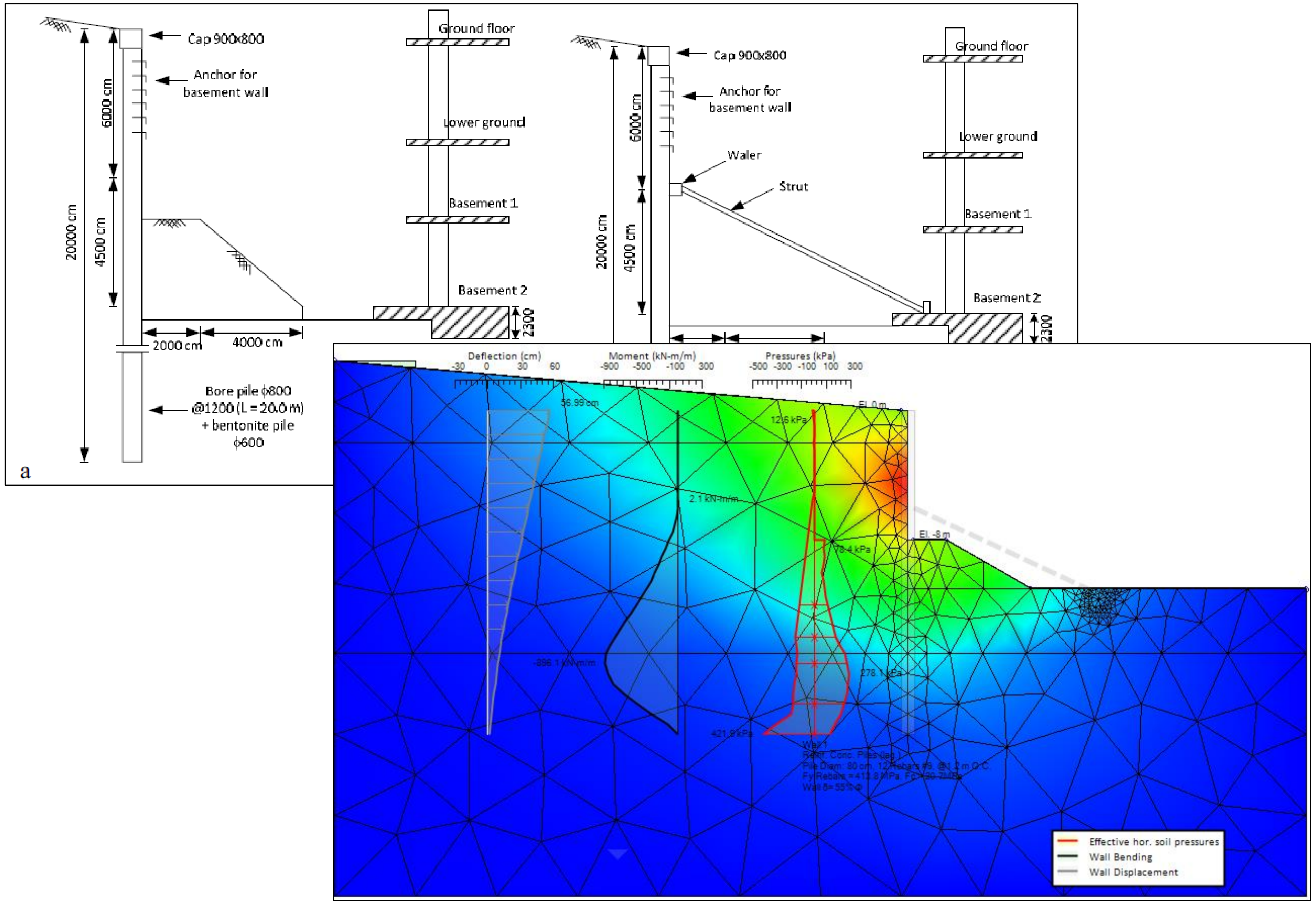
Wall Section Properties

X-Coordinate	X = 0
Top Elevation	Z = 0
Wall Type	Secant Piles
Pile Section	2.5 ft Diam. Concrete Piles
Pile Spacing	4 ft
Reinforcement	8#8 Bars, #4 Shear Reinf.

Support Properties

Support	Top Level	Second Level
Elevation	Z = -8 ft	Z = -18 ft
Section Type	W16X100	W16X100

Deep Excavation Case Studies



Access deepexcavation.com
Review Case Studies

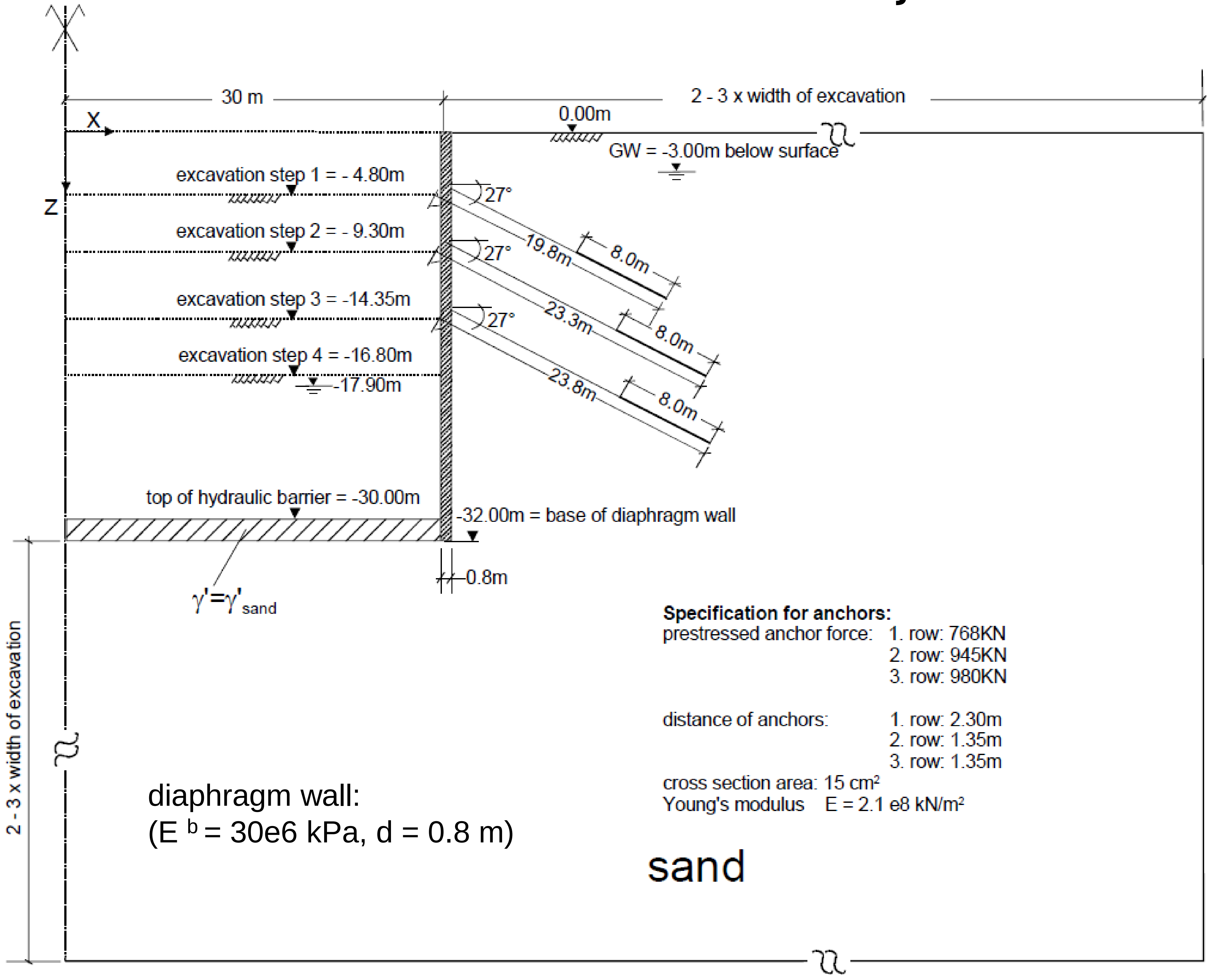
BERLIN EXCAVATION
(benchmark case study)

German Society for Geotechnics benchmark excavation (2002)

- Selected an existing excavation in berlin (with monitoring results and detailed soil investigation)
- Sent to various university institutes and consulting companies known to deal with Excavation numerical analysis.
- Gathered analysis results and created a comprehensive report

Example with prescribed properties as published By Schweiger.

depth of layer	E_{50}^{ref}	E_{ur}^{ref}	E_{oed}^{ref}	ν	P	c	$<_{ur}$	p_{ref}	m	R_f	R_{inter}
m	kPa	kPa	kPa	°	°	kPa	-	kPa	-	-	-
0 - 20	45 000	180 000	45 000	35	5	1.0	0.2	100	0.55	0.9	0.8
20 - 40	75 000	300 000	75 000	38	6	1.0	0.2	100	0.55	0.9	0.8
> 40	105 000	315 000	105 000	38	6	1.0	0.2	100	0.55	0.9	-



German Society for Geotechnics benchmark excavation (2002)

Stage GF: Greenfield conditions (Ko based imposed stress field)
Stage 0: activation of diaphragm wall
Stage 1: excavation at level -4.8m
Stage 2: activation of anchor 1 and prestressing and groundwater lowering to -9.4m
Stage 3: excavation at level -9.3m
Stage 4: activation of anchor 2 and prestressing
Stage 5: groundwater lowering to -14.5m
Stage 6: excavation at level -14.35m
Stage 7: activation of anchor 3 and prestressing
Stage 8: groundwater lowering to -17.9m
Stage 9: final excavation at level -16.8m

German Society for Geotechnics benchmark excavation (2002)

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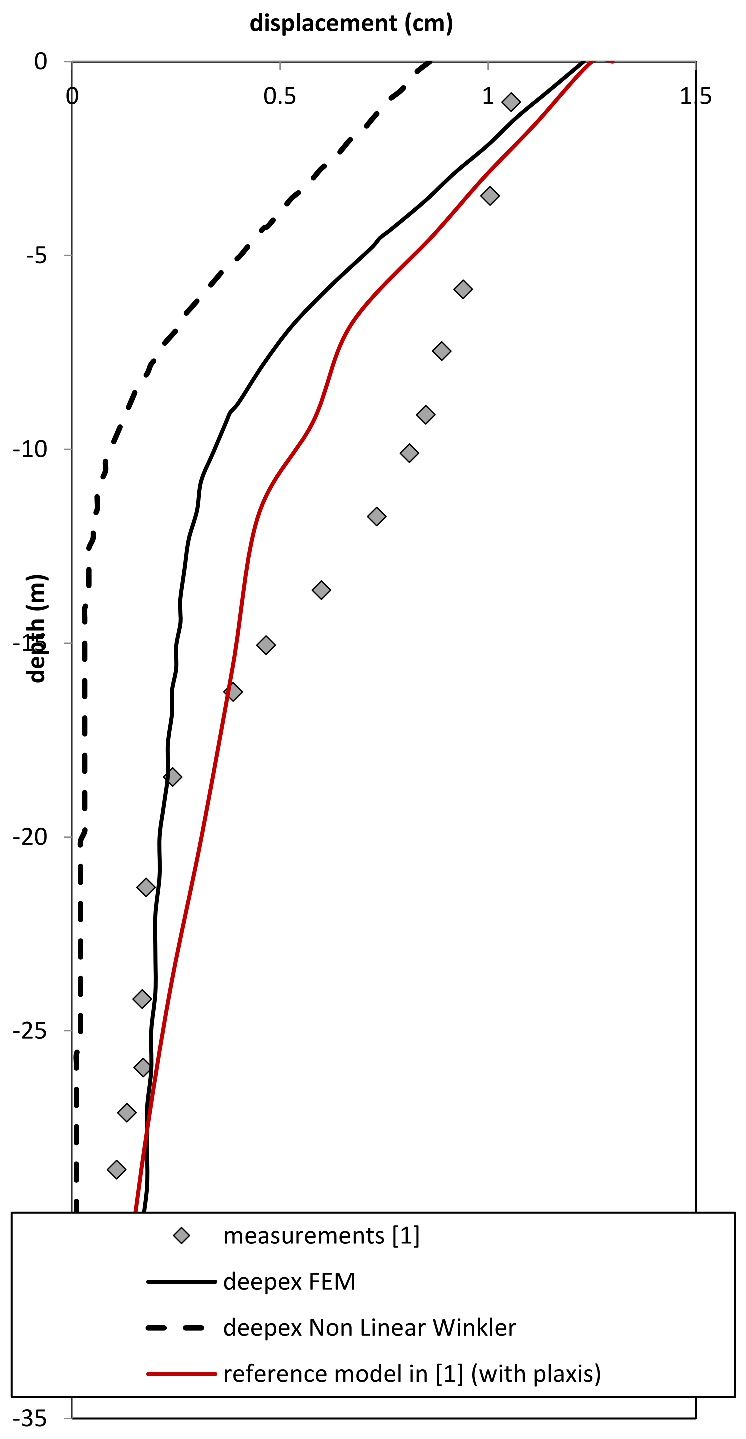
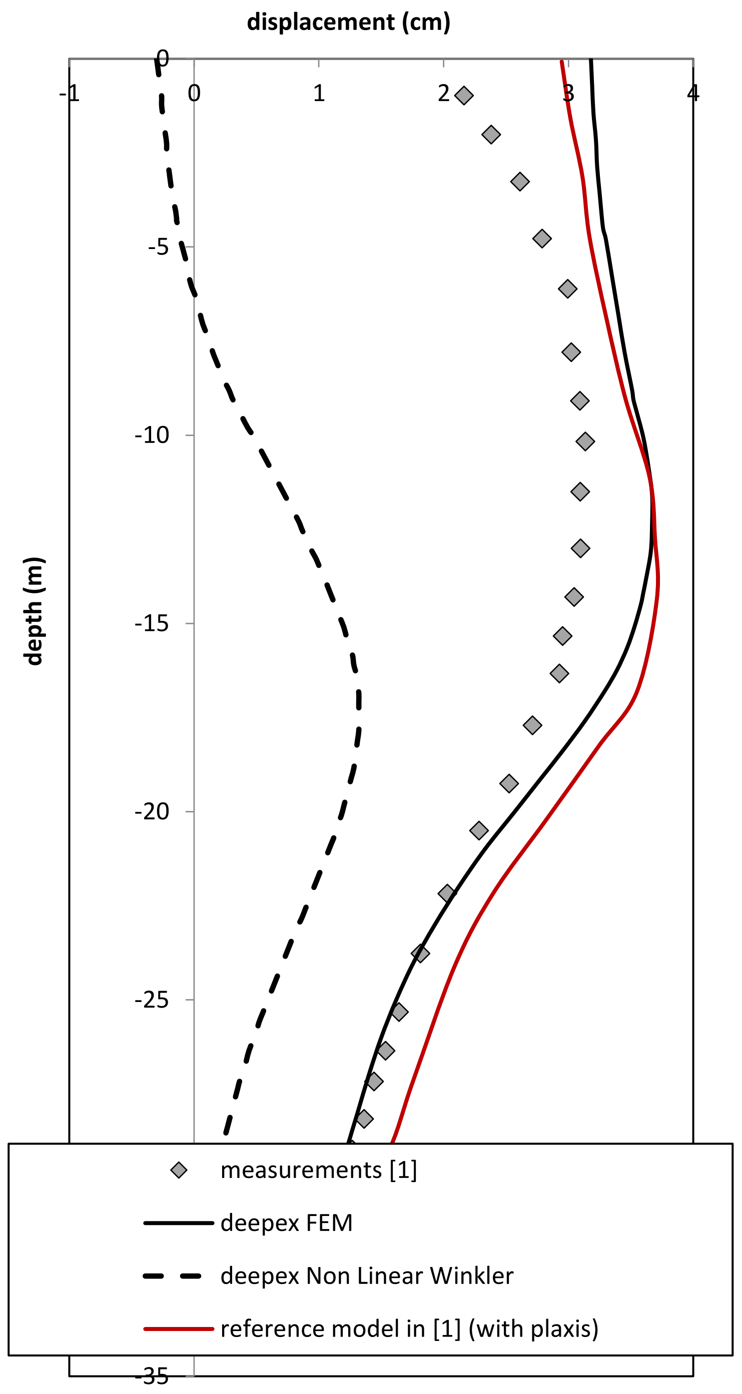


Stage 1

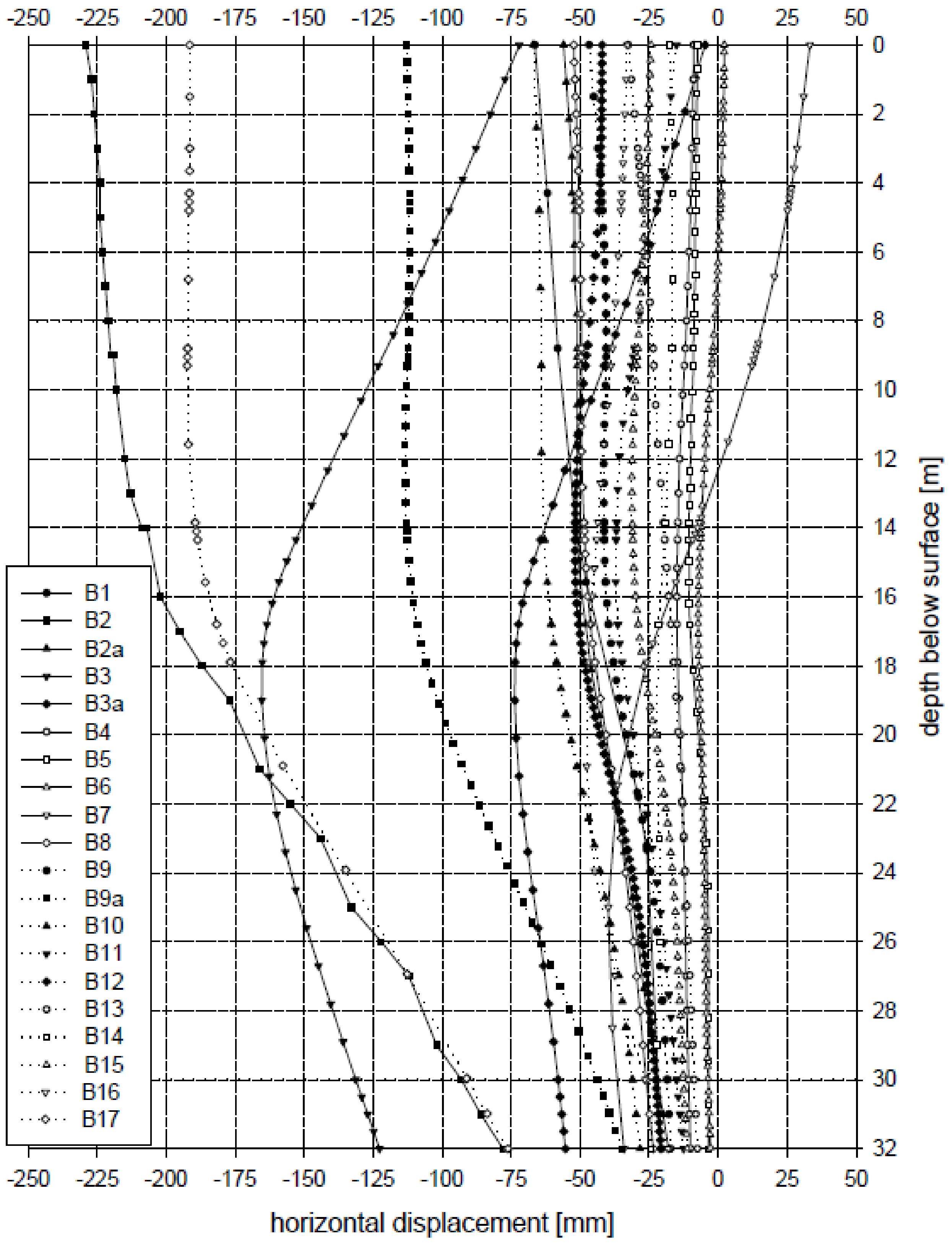


Stage 9

German Society for Geotechnics benchmark excavation (2002)

- Most participants trusted the strength indicated from the experiments
- stiffness generated from the tests was considered too low by many participants
- significant variation was observed however in the assumption of the dilatancy angle ψ, ranging from 0° to 15°.

German Society for Geotechnics benchmark excavation (2002)

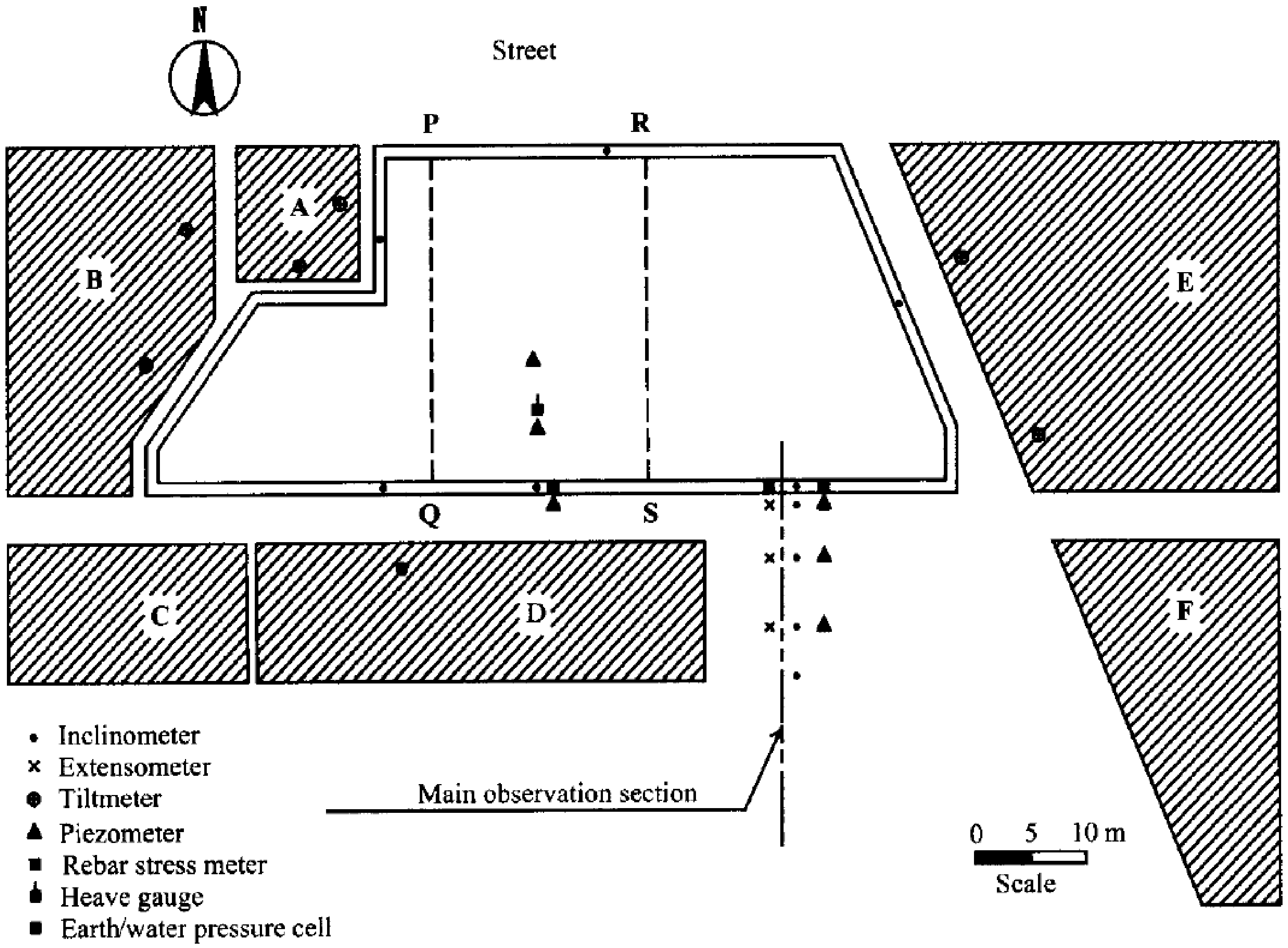


- Some of the participants used an incorrect stiffness
- some participants incorrectly calculated the prestress force
- Mohr coulomb based models
- Fixed anchors
- the difference in modelling the groundwater lowering (0.5-1.5cm)

Major issues where caused by the selection of the soil properties prior to the FEM model construction

EXCAVATION OF TAIPEI NATIONAL ENTERPRISE CENTER

TNEC



(a)

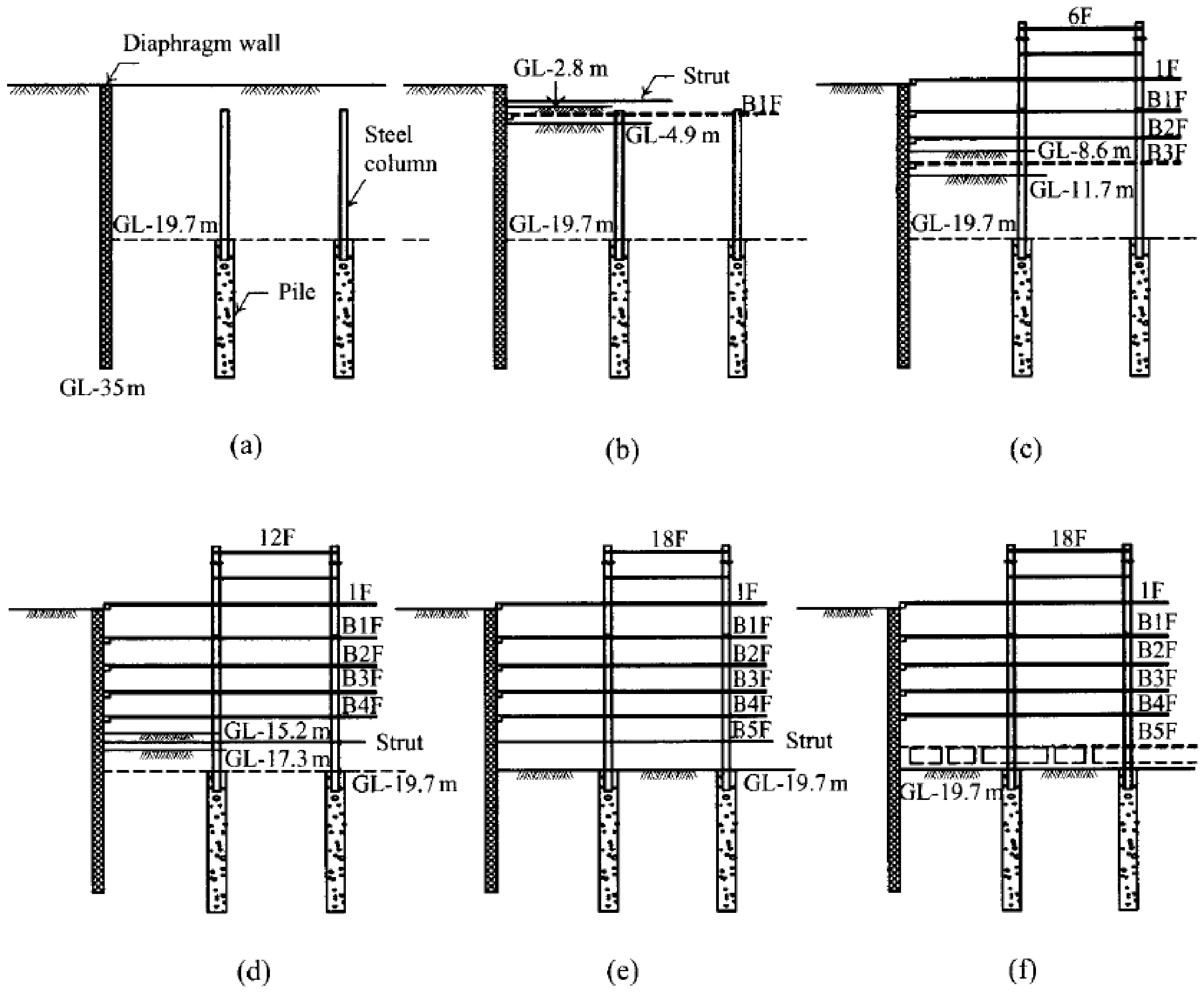


Figure 3.34 Construction procedure of the Taipei National Enterprise Center (see Table 3.3 for the description of the construction procedure).

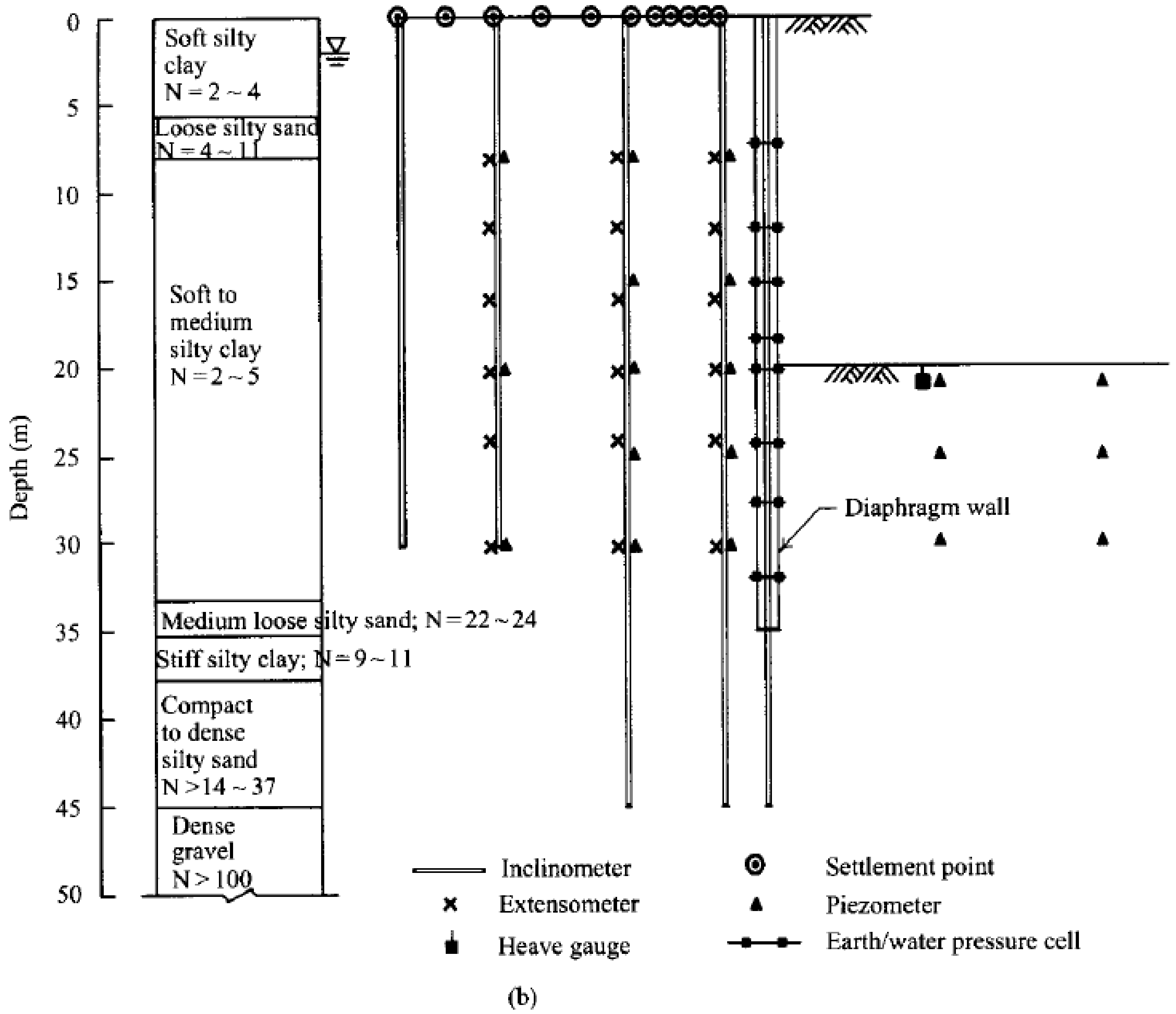
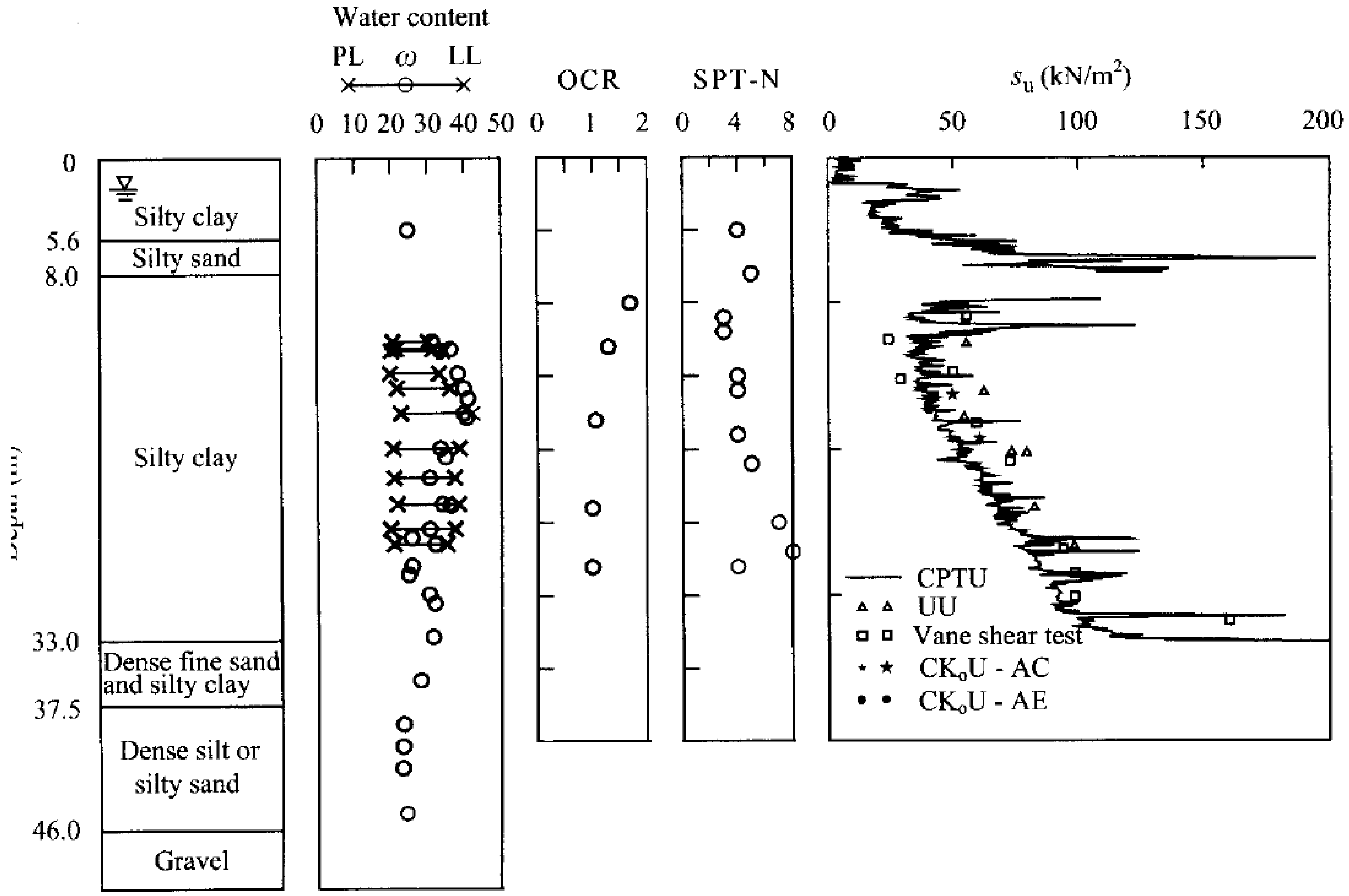


Figure 3.33 Excavation of the Taipei National Enterprise Center: (a) plan and (b) profile.

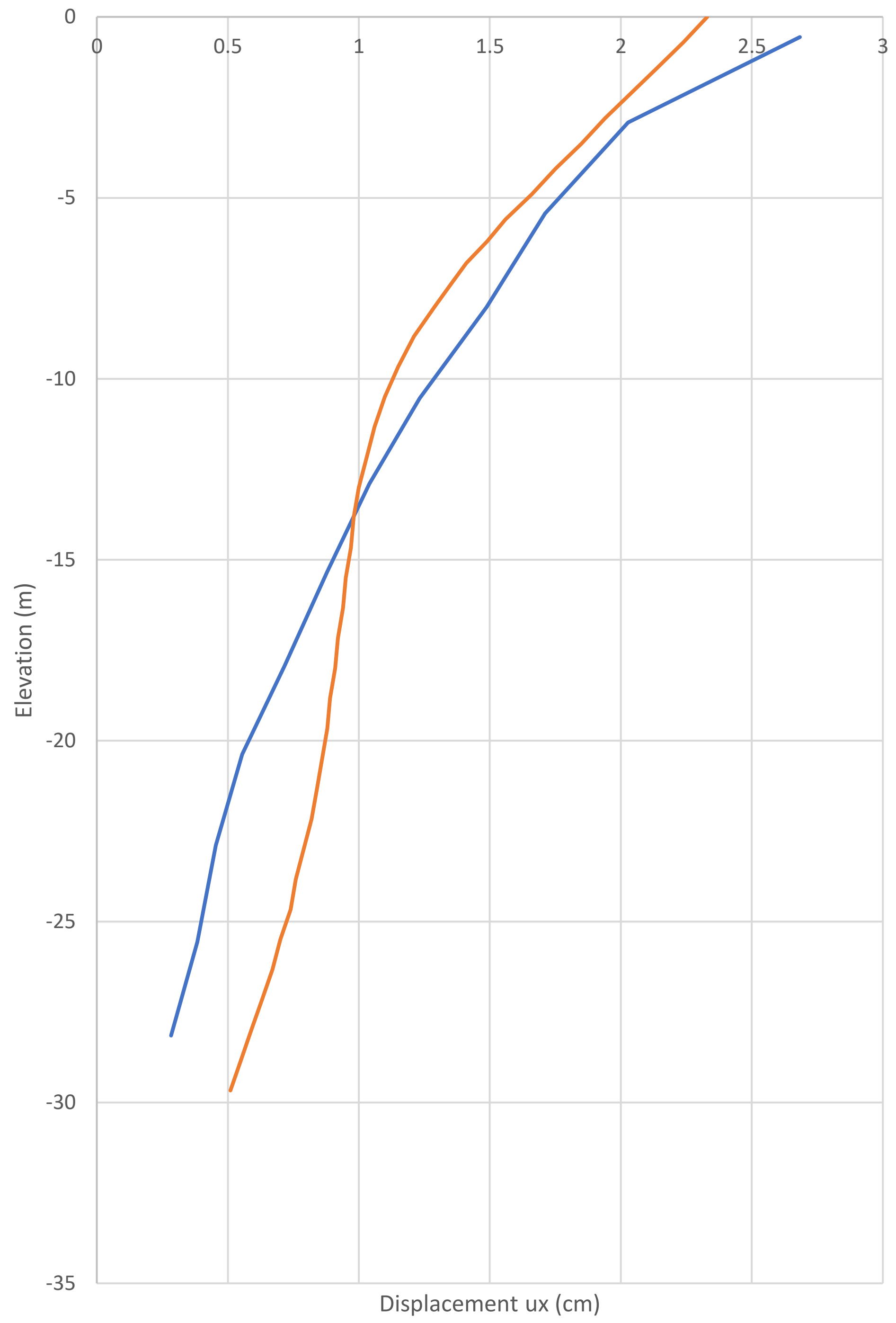
Table 3.3 Excavation process of TNEC

Stage	*Day*	*Excavation activities*
	−29 ~	Installed devices outside of the excavation zone, including in-soil inclinometers, extensometers, observation wells, and electronic piezometers
	1–89	Constructed the diaphragm wall, including installation of the earth/water pressure cells, in-wall rebar strain meters, and in-wall inclinometers
	89–147	Constructed piles and the steel columns
	147–155	Installed devices inside of the excavation zone, including the piezometers and heave gauges
1	156–162	Excavated to the depth of GL-2.80 m
2	164–169	Installed struts H 300 × 300 × 10 × 15 at the depth of GL-2.0 m. The preload of each strut = 784.8 kN
3	181–188	Excavated to the depth of GL-4.9 m
4A	217	Constructed B1F floor slab at the depth of GL-3.5 m
4B	222–238	Dismantled the first level of strut and constructed the 1F floor slab. Started the construction of the superstructure
5	233–255	Excavated to the depth of GL-8.6 m
6	279	Constructed the B2F floor slab at the depth of GL-7.1 m
7	318–337	Excavated to the depth of GL-11.8 m
8	352	Constructed the B3F floor slab at the depth of GL-10.3 m
9	363–378	Excavated to the depth of GL-15.2 m
10	400	Constructed the B4F floor slab at the depth of GL-13.7 m
11A	419–423	Excavated the central zone to the depth of GL-17.3 m
12A	425–429	Installed struts H 400 × 400 × 13 × 21 at the depth of GL-16.5 m in the central zone. The preload of each strut = 1177 kN
11B	430–436	Excavated the side zones to the depth of GL-17.3 m
12B	437–444	Installed struts H 400 × 400 × 13 × 21 in the two side zones at the depth of GL-16.5 m. The preload of each strut = 1177 kN
13	445–460	Excavated to the depth of GL-19.7 m
	457	Finished the superstructure
14	464–468	Cast the foundation slab
15	506–520	Constructed the B5F floor slab at the depth of GL-17.1 m
16	528	Dismantled the second level of struts

TNEC


Water content
PL ω LL
0 10 20 30 40 50
OCR
0 1 2
SPT-N
0 4 8
s_u (kN/m^2)
0 50 100 150 200
0
5.6
8.0
33.0
37.5
46.0
Silty clay
Silty sand
Silty clay
Dense fine sand and silty clay
Dense silt or silty sand
Gravel
CPTU
UU
Vane shear test
CK$_o$U - AC
CK$_o$U - AE

TNEC



SHANGHAI METRO TUNNELS

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SHANGHAI METRO TUNNELS- HU (2003)

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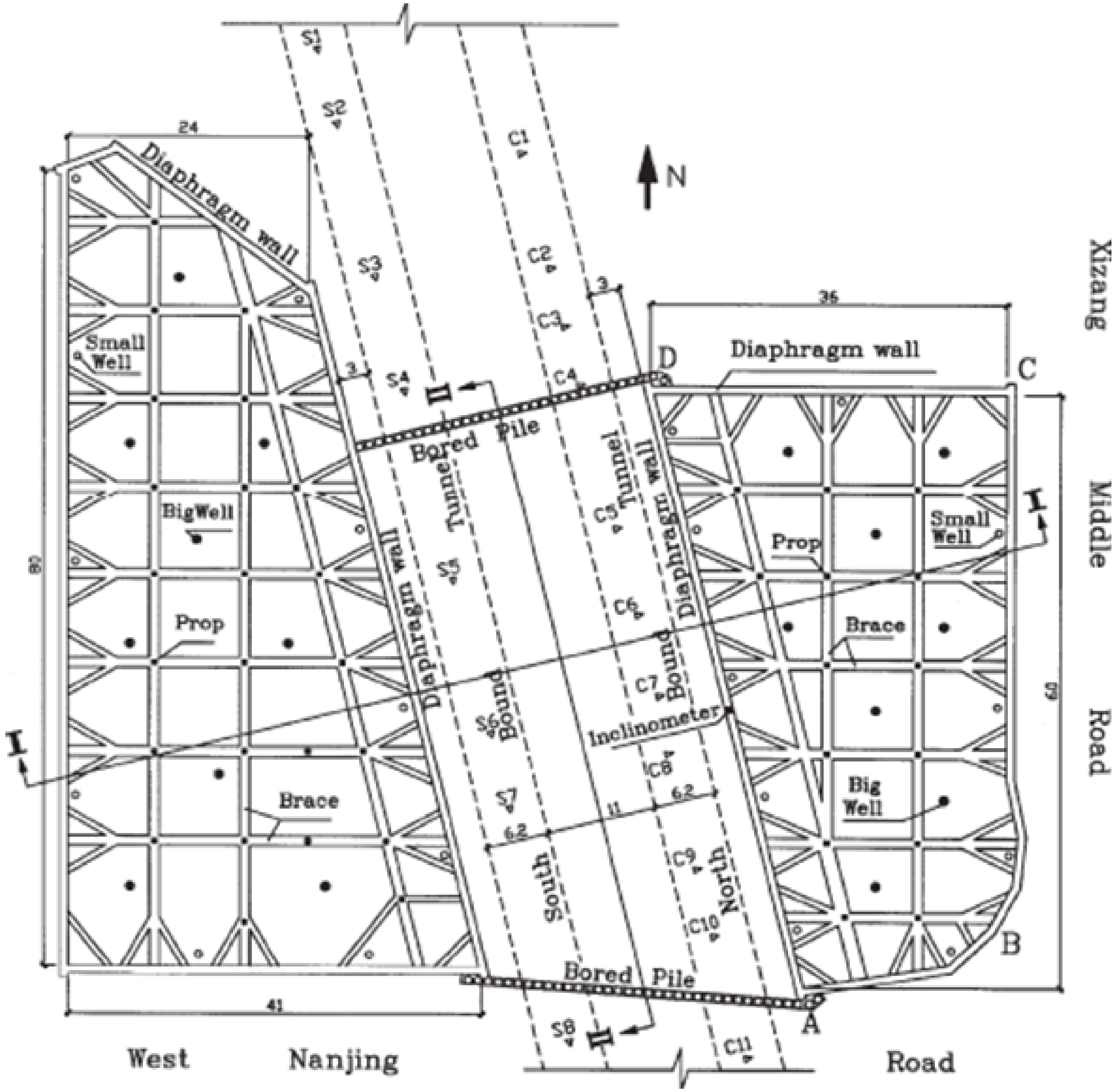

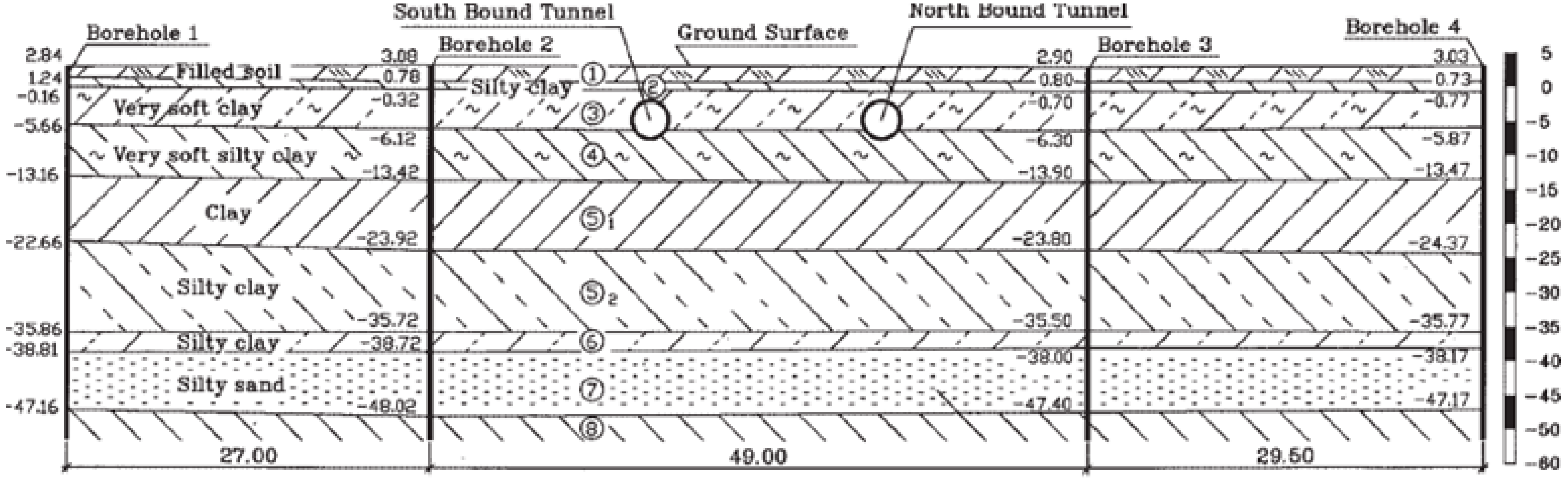

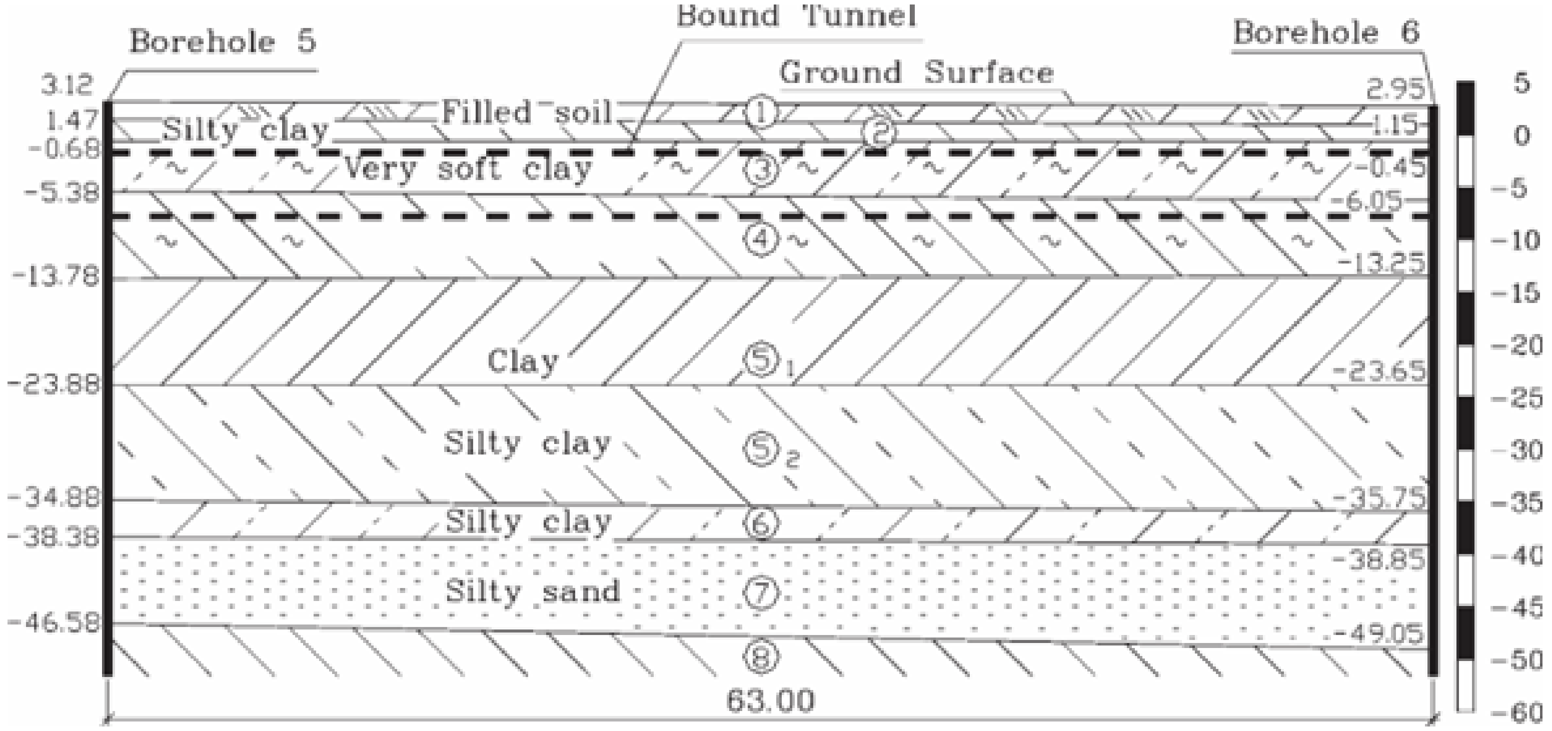

SHANGHAI METRO TUNNELS- HU (2003)

Stage GF: Greenfield conditions (Ko based imposed stress field)
Stage 0: activation of diaphragm wall
Stage 1: excavation at level -4.8m
Stage 2: activation of anchor 1 and prestressing and groundwater lowering to -9.4m
Stage 3: excavation at level -9.3m
Stage 4: activation of anchor 2 and prestressing
Stage 5: groundwater lowering to -14.5m
Stage 6: excavation at level -14.35m
Stage 7: activation of anchor 3 and prestressing
Stage 8: groundwater lowering to -17.9m
Stage 9: final excavation at level -16.8m

Conclusions

- Design of deep excavations has high epistemic and aleatory uncertainty
- Different levels of verification are essential
- At the end of the day numerical models are just tools

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Part 5

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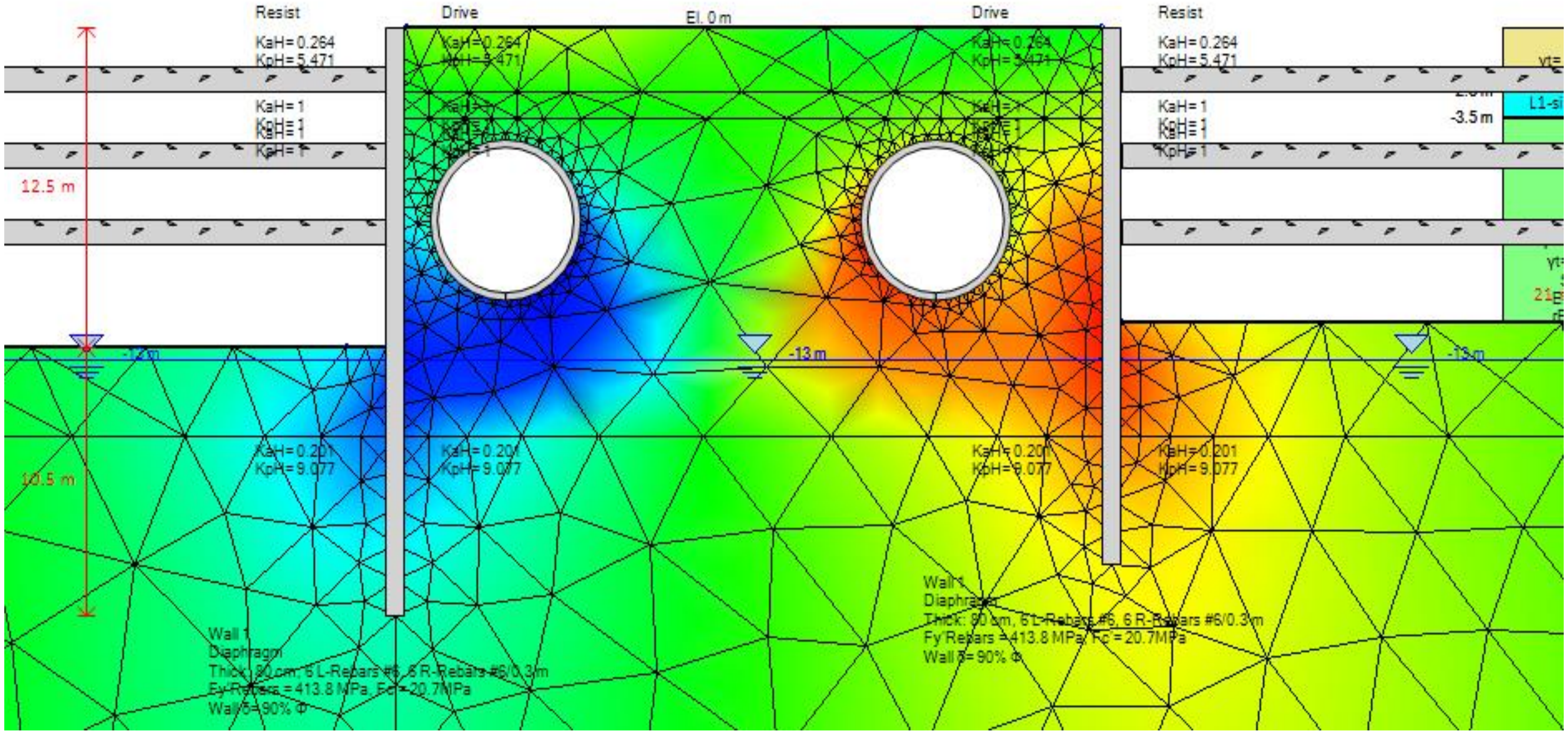
Finite Element Analysis and Tunnels



- ✓ DeepEX 2D FEM Engine (DeepFEM)
- ✓ Consider full soil-structure interaction
- ✓ Automatic FE options
- ✓ Soil Models for FEM
- ✓ Include Tiedowns & Foundation Piles

Tunnel Options:

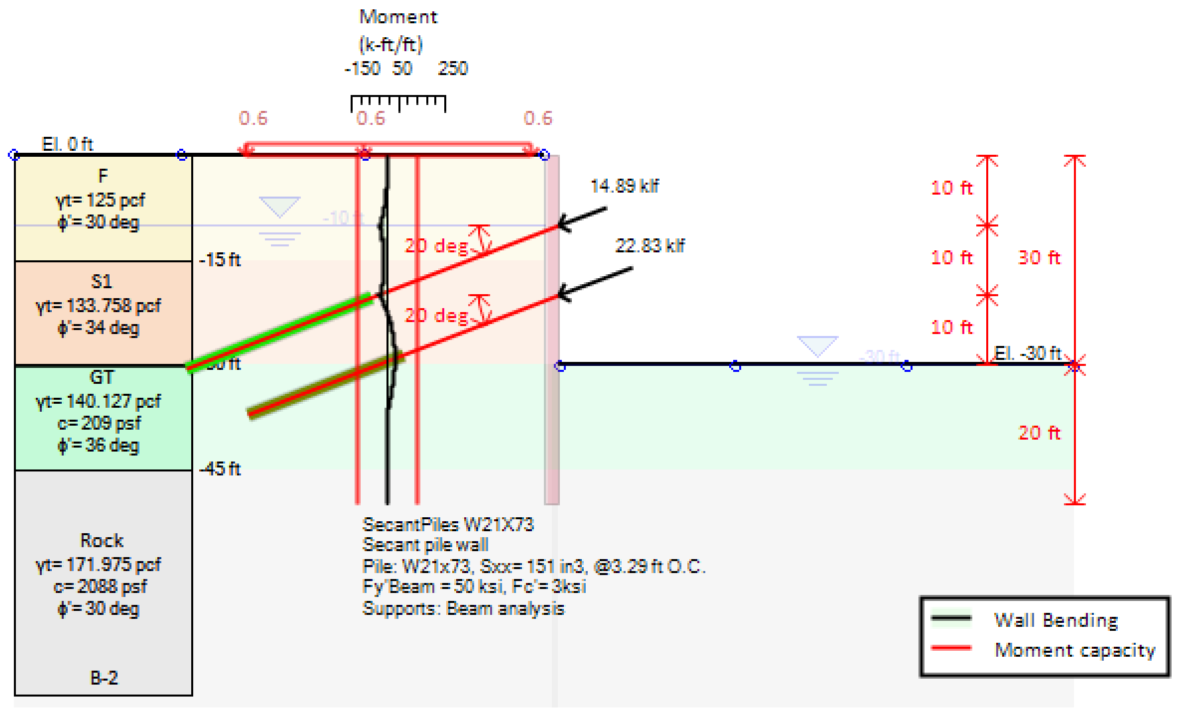
- ✓ Tunnel Analysis with FEM
- ✓ TBM Tunnels
- ✓ NATM - SEM Tunnels
- ✓ Oval and Complex Tunnel Shapes
- ✓ Tunnel Model Wizard
- ✓ Cut-and-Cover Tunnels

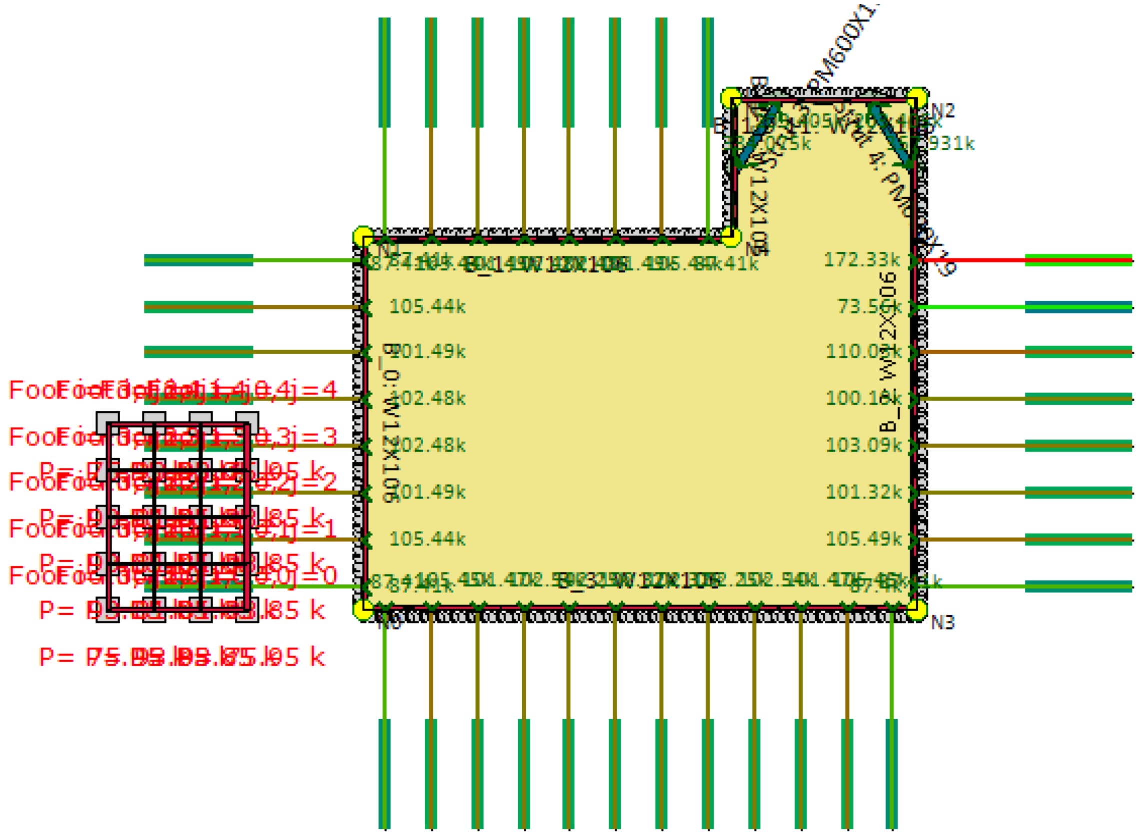
DeepEX Shoring Design Software

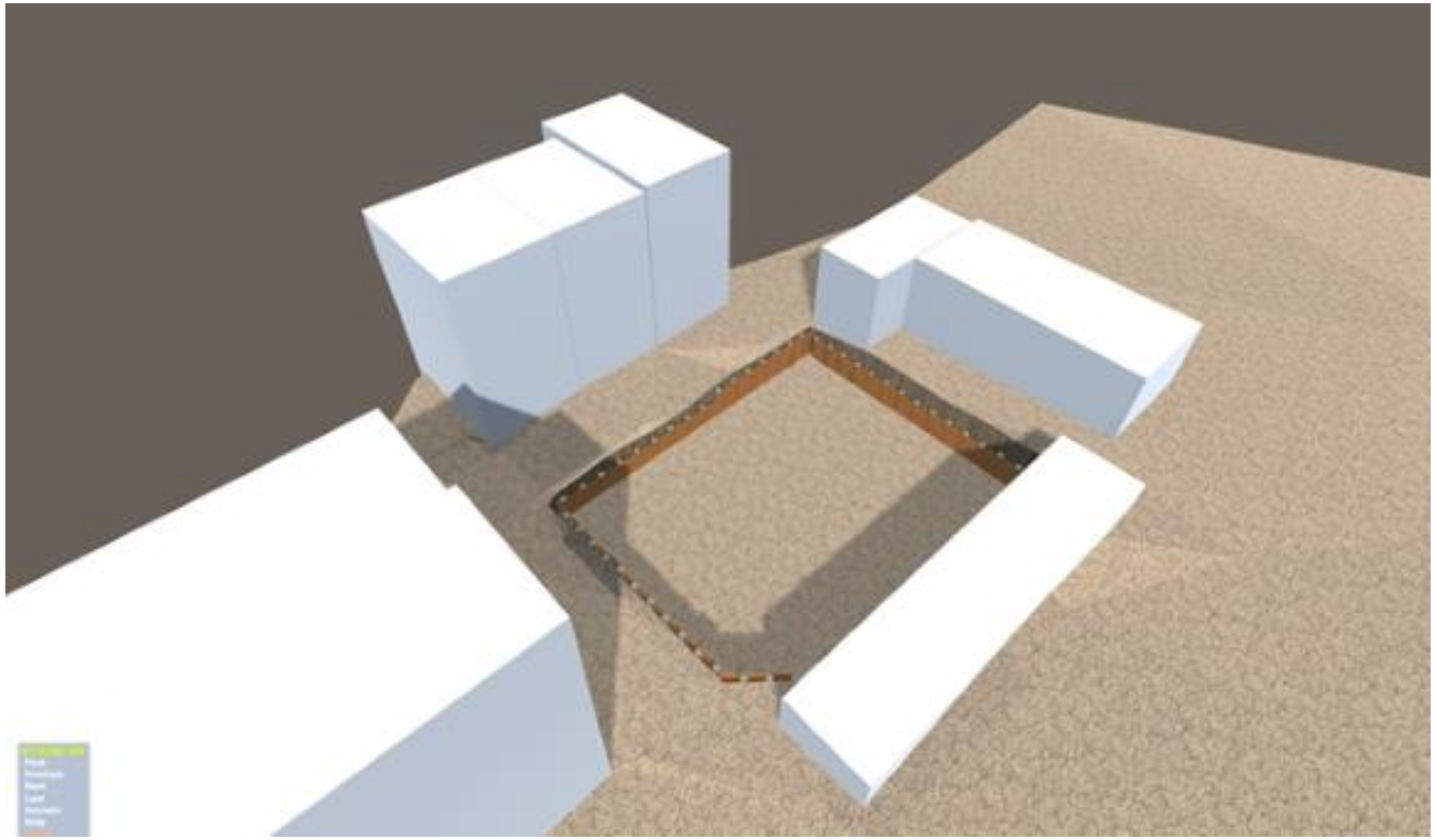
2D Sections & 3D Models, 3D Holograms

www.deepexcavation.com

- ✓ Full Design - 2D Sections and 3D Model
- ✓ Structural & Geotechnical design of Tiebacks and Struts
- ✓ 3D Building Loads
- ✓ Full Model Optimization (Walls and Supports)
- ✓ Virtual Reality Model Visualization - Export Model to HoloDeepEX







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Shoring Design Software

Check & Optimize Steel Connections

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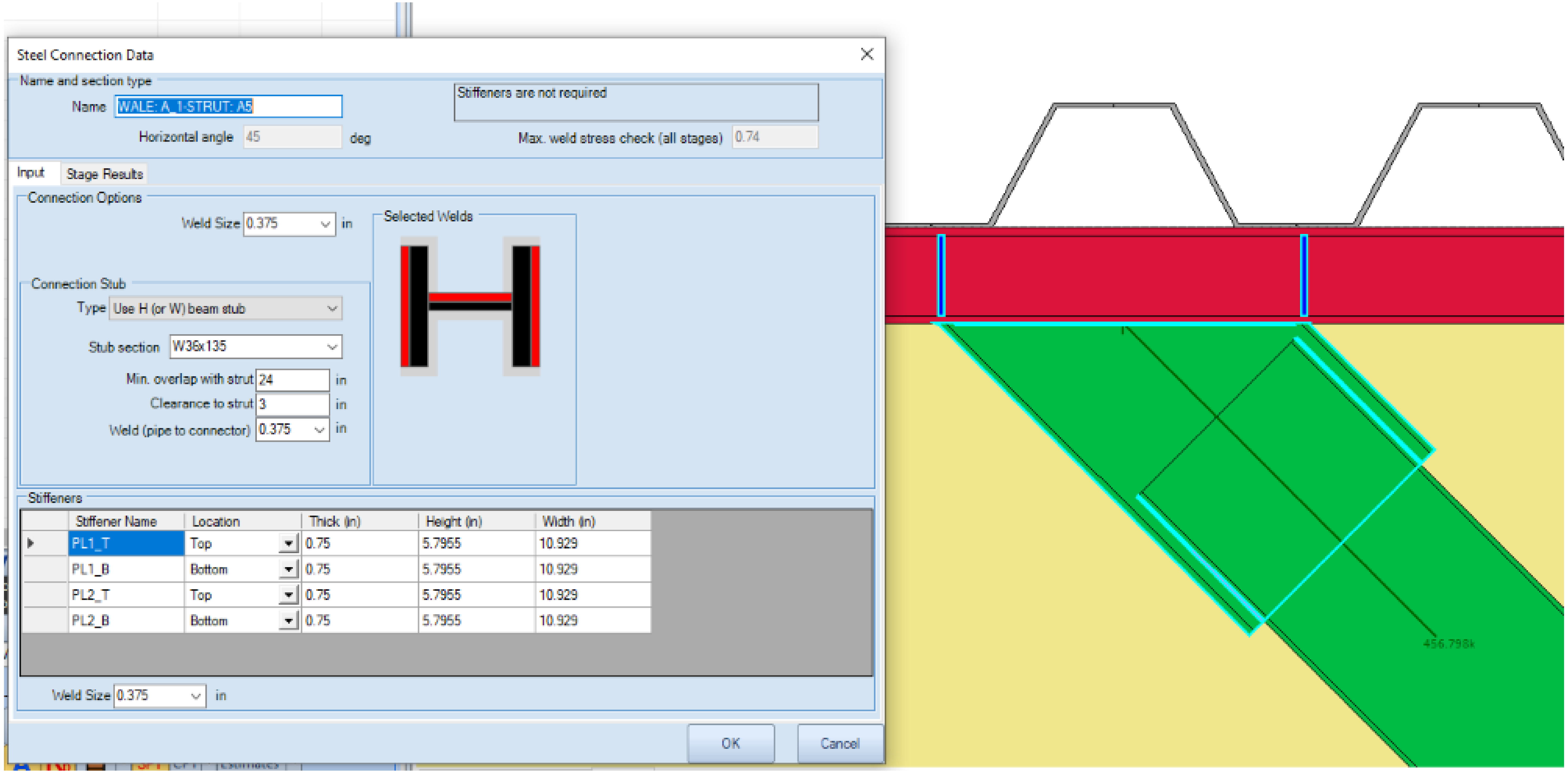
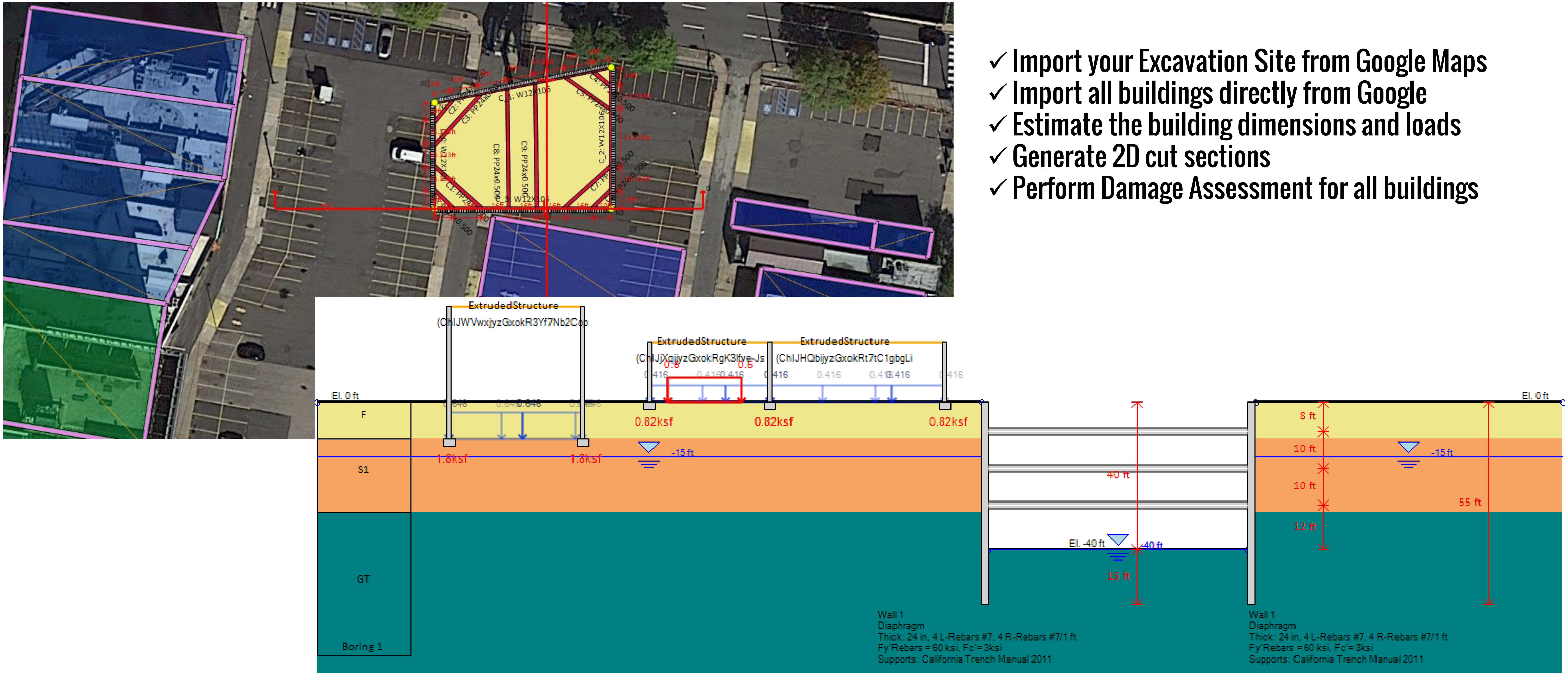


- ✓ Generate all steel connections
- ✓ Check Steel Connections (Struts and Walers)
- ✓ Optimize Steel Connections with a Click
- ✓ Adjust weld sizes and apply plate stiffeners

Import Site Map & Buildings from Google



- ✓ Import your Excavation Site from Google Maps
- ✓ Import all buildings directly from Google
- ✓ Estimate the building dimensions and loads
- ✓ Generate 2D cut sections
- ✓ Perform Damage Assessment for all buildings

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Building Damage Assessment

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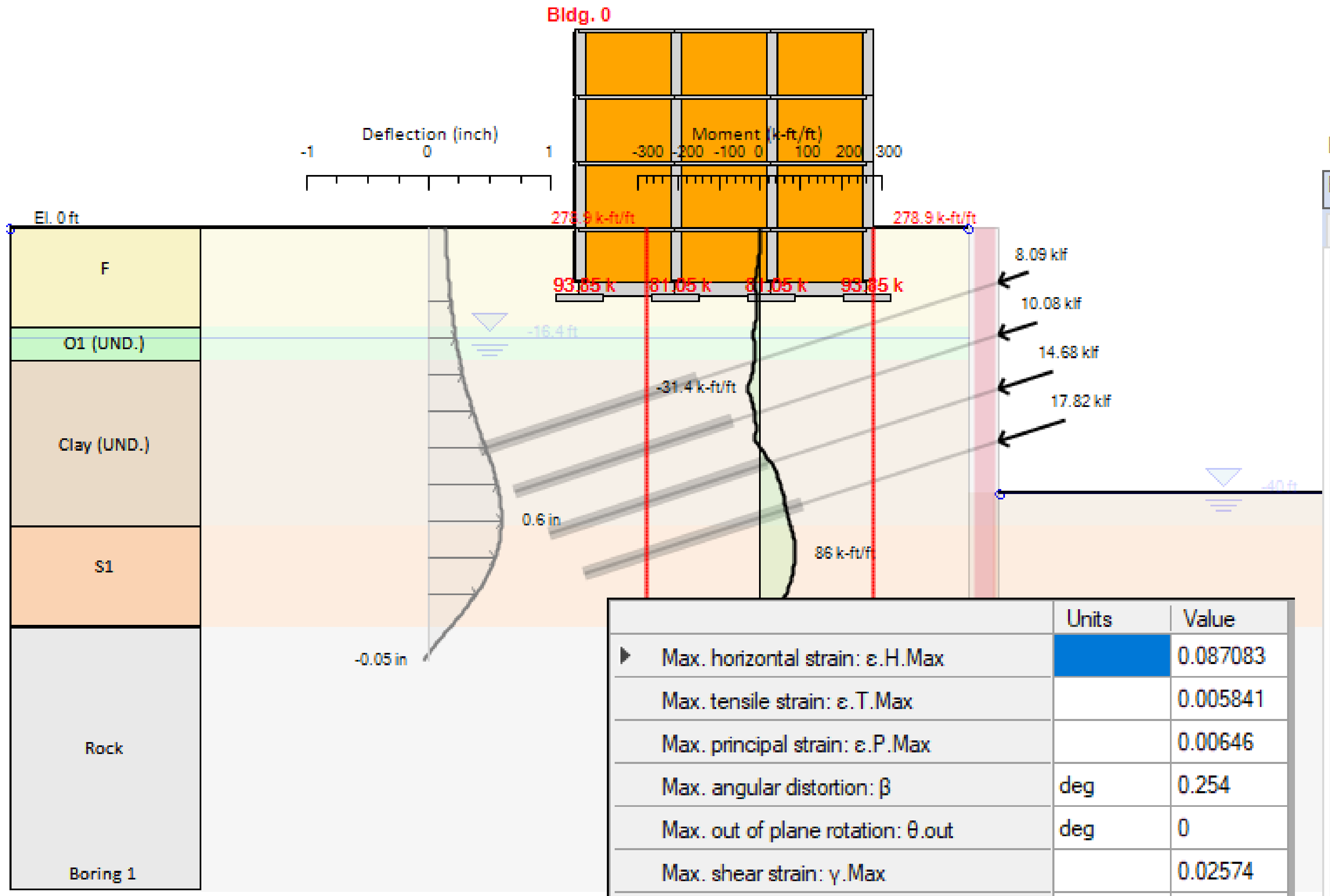
- ✓ Perform Damage Assessment of all Buildings close to an excavation site
- ✓ Review Crack widths, Damage Categories, Strains etc. for all building walls.



	Units	Value
Max. horizontal strain: ε.H.Max		0.087083
Max. tensile strain: ε.T.Max		0.005841
Max. principal strain: ε.P.Max		0.00646
Max. angular distortion: β	deg	0.254
Max. out of plane rotation: θ.out	deg	0
Max. shear strain: γ.Max		0.02574
Ave. shear strain: γ.Ave		0.003359
Cumulative principal crack width C.p	in	0.2936
Cumulative tensile crack width C.t	in	0.3409
Max principal crack width Cr.p.Max	in	0.1957
Max tensile crack width Cr.t.Max	in	0.2273
Max. damage category		Moderate
Damage category crack width		Moderate
Damage category Boscardin Cording		Moderate

Building Damage Results

Bldg. 0

Maximum values | All elements | Individual elements | Horizontal movement | Settlement | Boscardin-Cording Chart | Hogging Chart (Burland 1979)

		θ.out	γ.Max	γ.Ave	C.p (in)	C.t (in)	Cr.p (in)	Cr.t (in)	Damage Cat	Dam. Crack width	Dam. Boscardin
Bottom side continuous basement wall	203	0	0.005103	0.002551	0	0	0	0	Moderate	Negligibe	Moderate
Left side continuous basement wall	277	0	0.000752	0.000376	0	0	0	0	Negligibe	Negligibe	Negligibe
Right side continuous basement wall	926	0	0.002511	0.001256	0	0	0	0	Negligibe	Negligibe	Negligibe
Top side continuous basement wall		0	0	0	0	0	0	0	Negligibe	Negligibe	Negligibe
Exterior wall at floor 1El. 0, (-10.67, 30 to -20.67,30)	407	0	0.025554	0.001561	0.2327	0.3337	0.1551	0.2225	Moderate	Moderate	N/A
Exterior wall at floor 1El. 0, (-20.67, 70 to -10.67,70)		0	0	0	0	0	0	0	Negligibe	Negligibe	N/A
Exterior wall at floor 1El. 0, (-20.67, 30 to -30.67,30)	872	0	0.022453	0.002095	0.0798	0.0299	0.0532	0.0199	Slight	Slight	N/A
Exterior wall at floor 1El. 0, (-30.67, 70 to -20.67,70)		0	0	0	0	0	0	0	Negligibe	Negligibe	N/A
Exterior wall at floor 1El. 0, (-30.67, 30 to -40.67,30)	558	0	0.014831	0.001949	0	0	0	0	Negligibe	Negligibe	N/A
Exterior wall at floor 1El. 0, (-40.67, 70 to -30.67,70)		0	0	0	0	0	0	0	Negligibe	Negligibe	N/A
Exterior wall at floor 1El. 0, (-10.67, 40 to -10.67,30)	439	0	0.02574	0	0.153	0.2154	0.102	0.1436	Slight	Slight	N/A
Exterior wall at floor 1El. 0, (-40.67, 30 to -40.67,40)	34	0	0.007772	0.001901	0	0	0	0	Negligibe	Negligibe	N/A
Exterior wall at floor 1El. 0, (-10.67, 50 to -10.67,40)	169	0	0.02417	0	0.2936	0.1803	0.1957	0.1202	Slight	Slight	N/A
Exterior wall at floor 1El. 0, (-40.67, 40 to -40.67,50)	391	0	0.002266	0	0	0	0	0	Negligibe	Negligibe	N/A
Exterior wall at floor 1El. 0, (-10.67, 60 to -10.67,50)	336	0	0.013545	0	0.0476	0	0.0317	0	Very slight	Very slight	N/A
Exterior wall at floor 1El. 0, (-40.67, 50 to -40.67,60)		0	0	0	0	0	0	0	Negligibe	Negligibe	N/A
Exterior wall at floor 1El. 0, (-10.67, 70 to -10.67,60)		0	0	0	0	0	0	0	Negligibe	Negligibe	N/A
Exterior wall at floor 1El. 0, (-40.67, 60 to -40.67,70)		0	0	0	0	0	0	0	Negligibe	Negligibe	N/A
Exterior wall at floor 2El. 10, (-10.67, 30 to -20.67,30)	407	0	0.025554	0.001561	0.1975	0.2805	0.1317	0.187	Slight	Slight	N/A
Exterior wall at floor 2El. 10, (-20.67, 70 to -10.67,70)		0	0	0	0	0	0	0	Negligibe	Negligibe	N/A
Exterior wall at floor 2El. 10, (-20.67, 30 to -30.67,30)	872	0	0.022453	0.002095	0.1566	0.2011	0.1044	0.1341	Slight	Slight	N/A

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Export All Project Sketches to DXF

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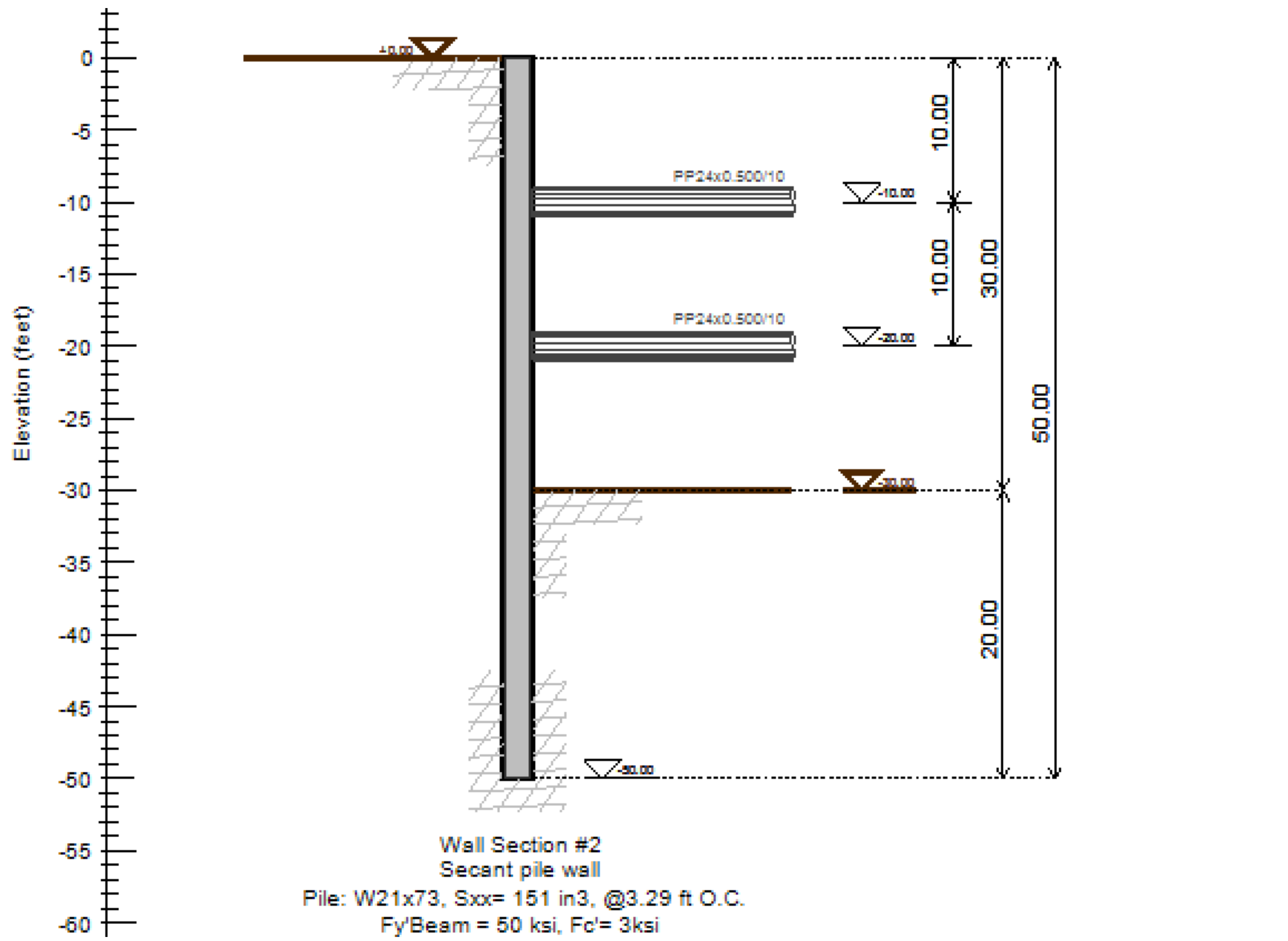
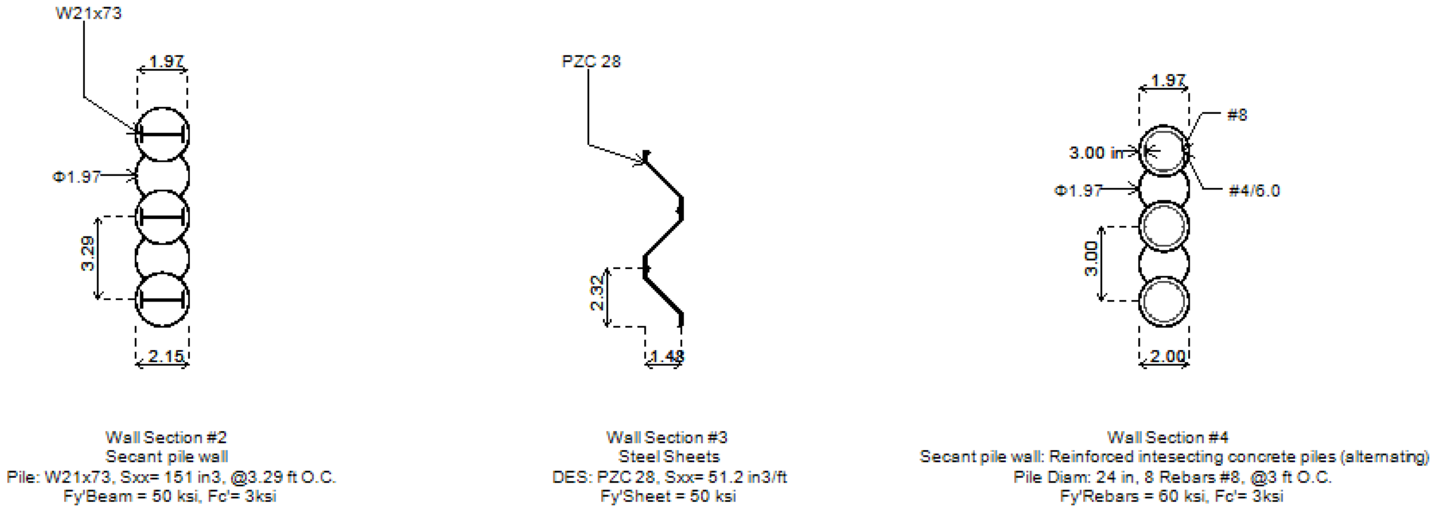


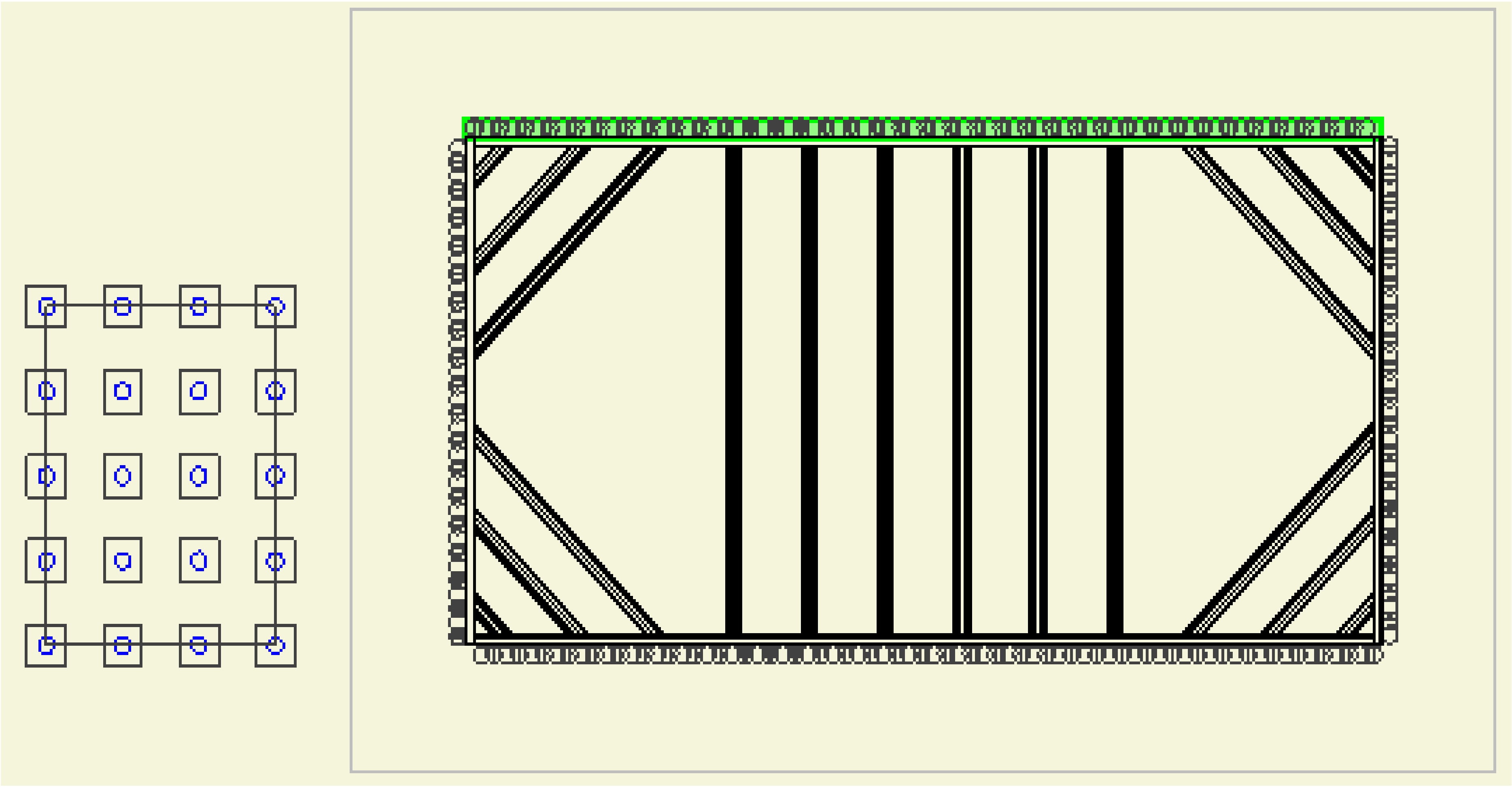


2D Sections:

✓ Export all 2D Sections Sketches for each Construction Stage
✓ Export Wall Section Details
✓ Export 2D Sections with Result Diagrams

3D Models:

✓ Export all 2D Sections and Wall Details
✓ Export Full Project Plan Sketches
✓ Export Elevation Sketches for each Project Wall



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Gravity Walls & Pile Abutments

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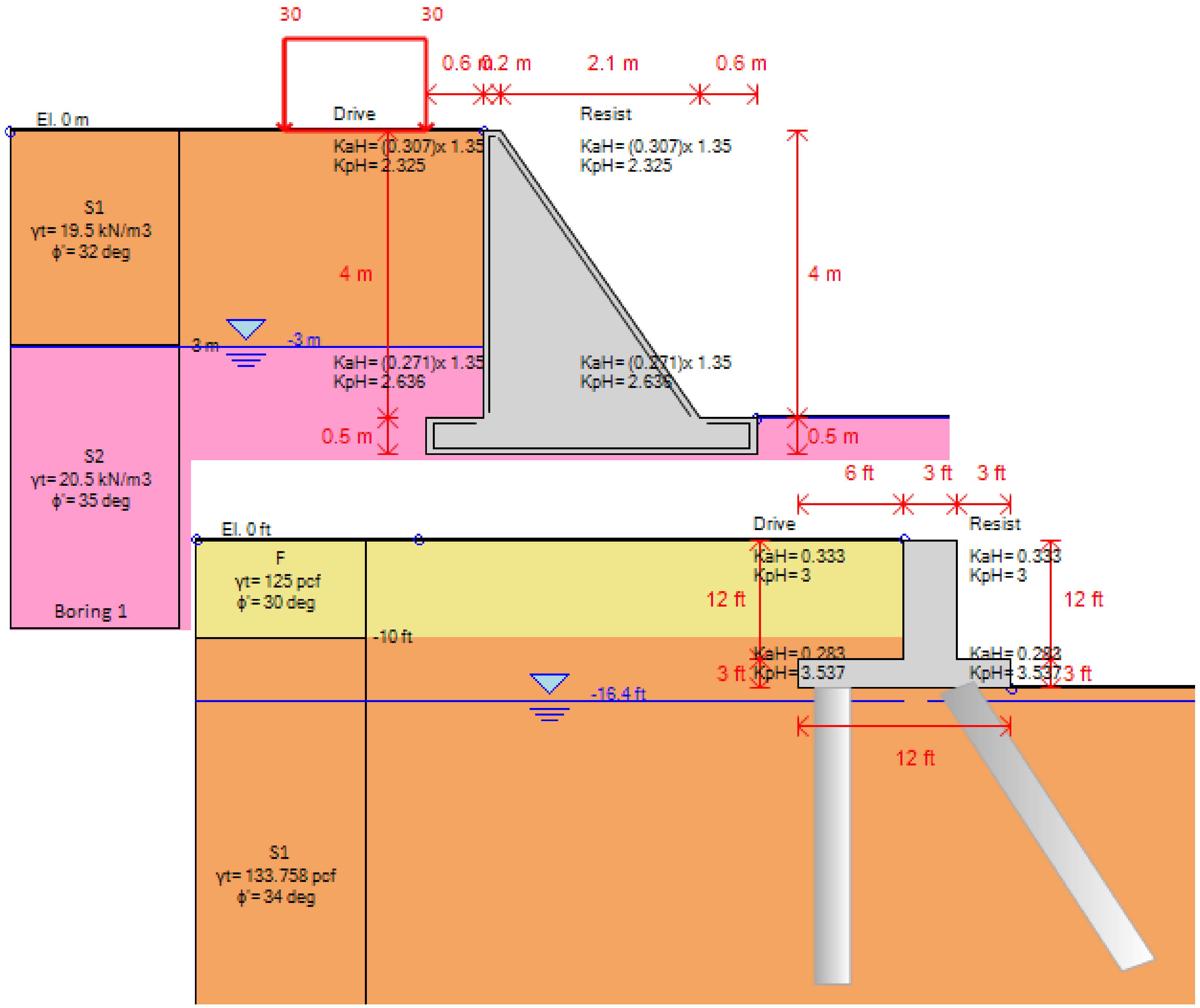
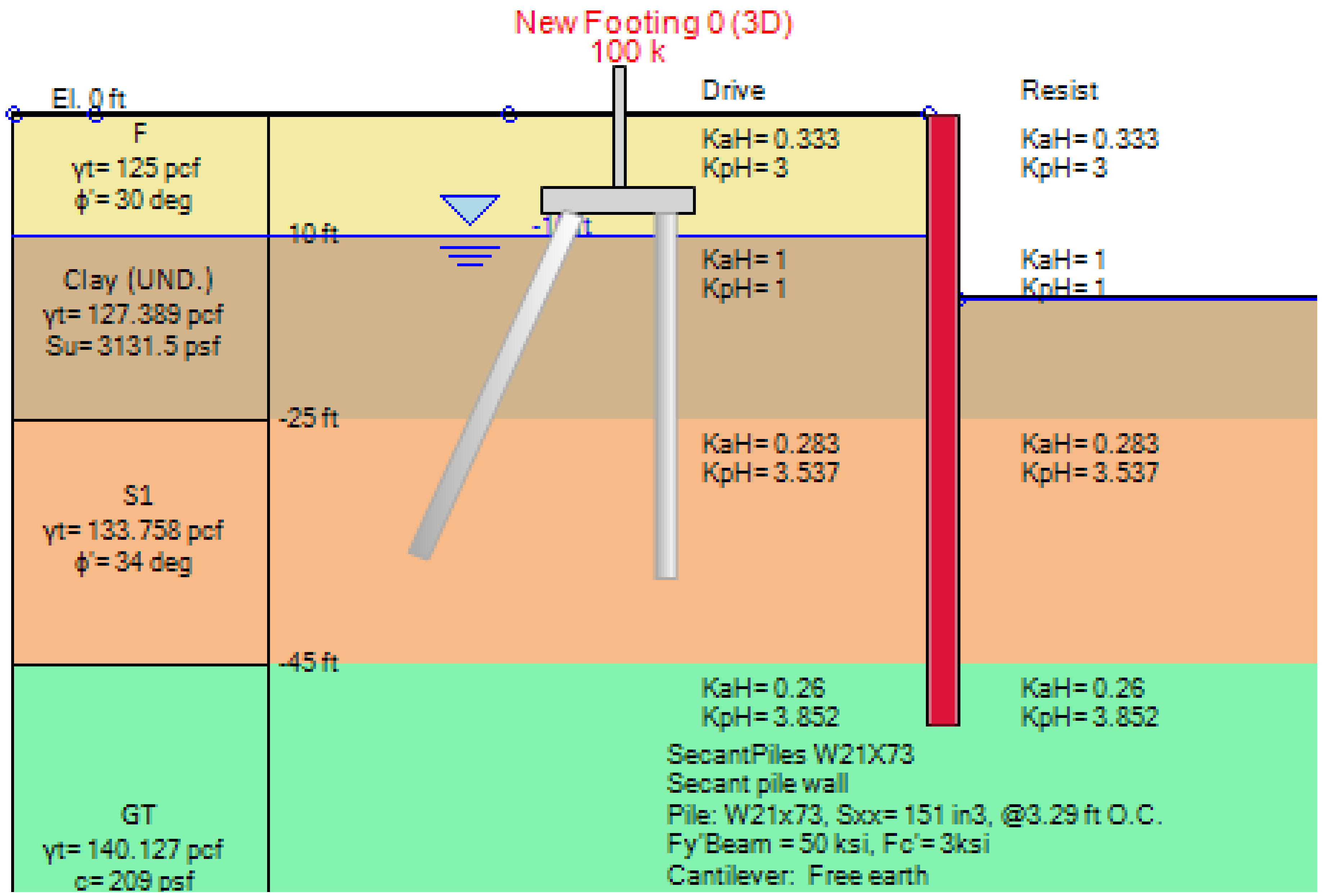
- ✓ Design gravity walls (any shape)
- ✓ Design pile supported abutments
- ✓ Use footings (3D loads) and design the foundation piles





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Sea Walls - Quay Walls - Wave Pressures

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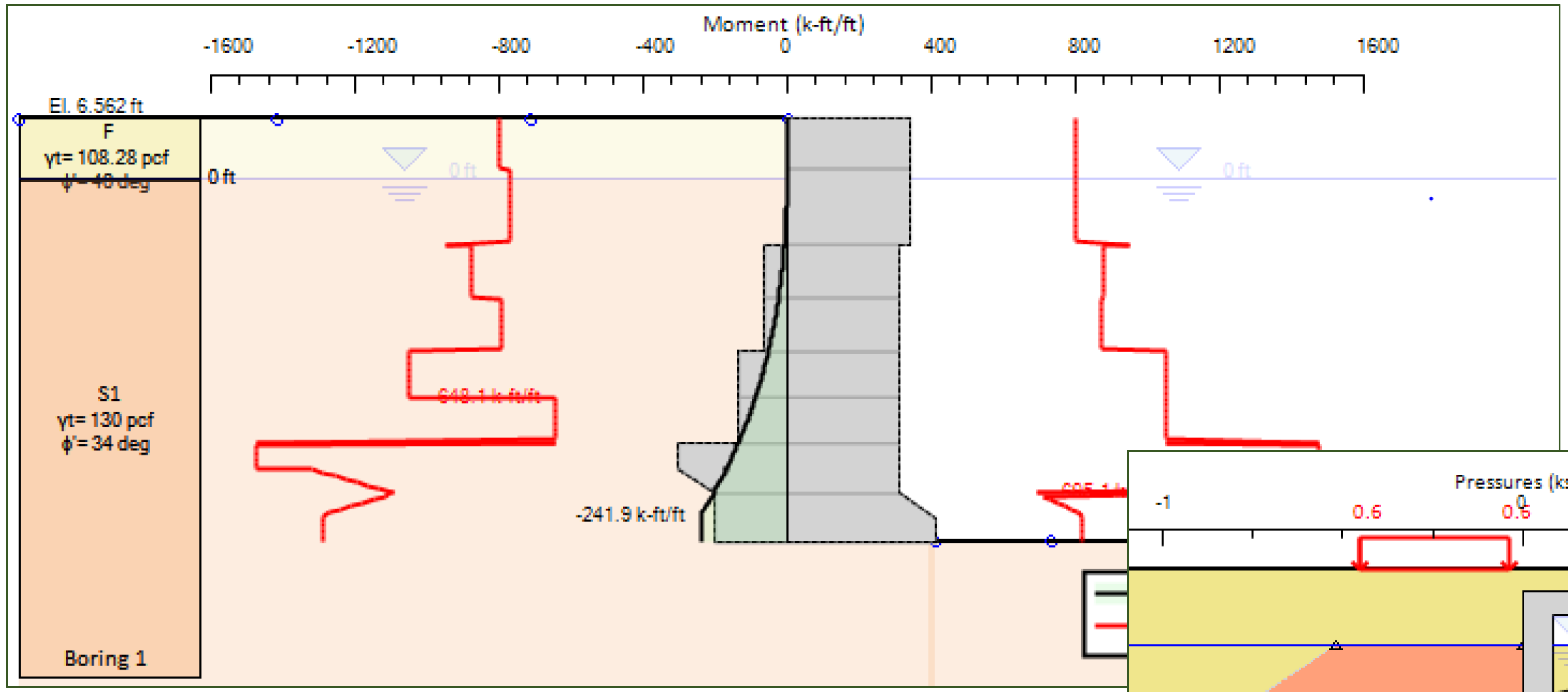
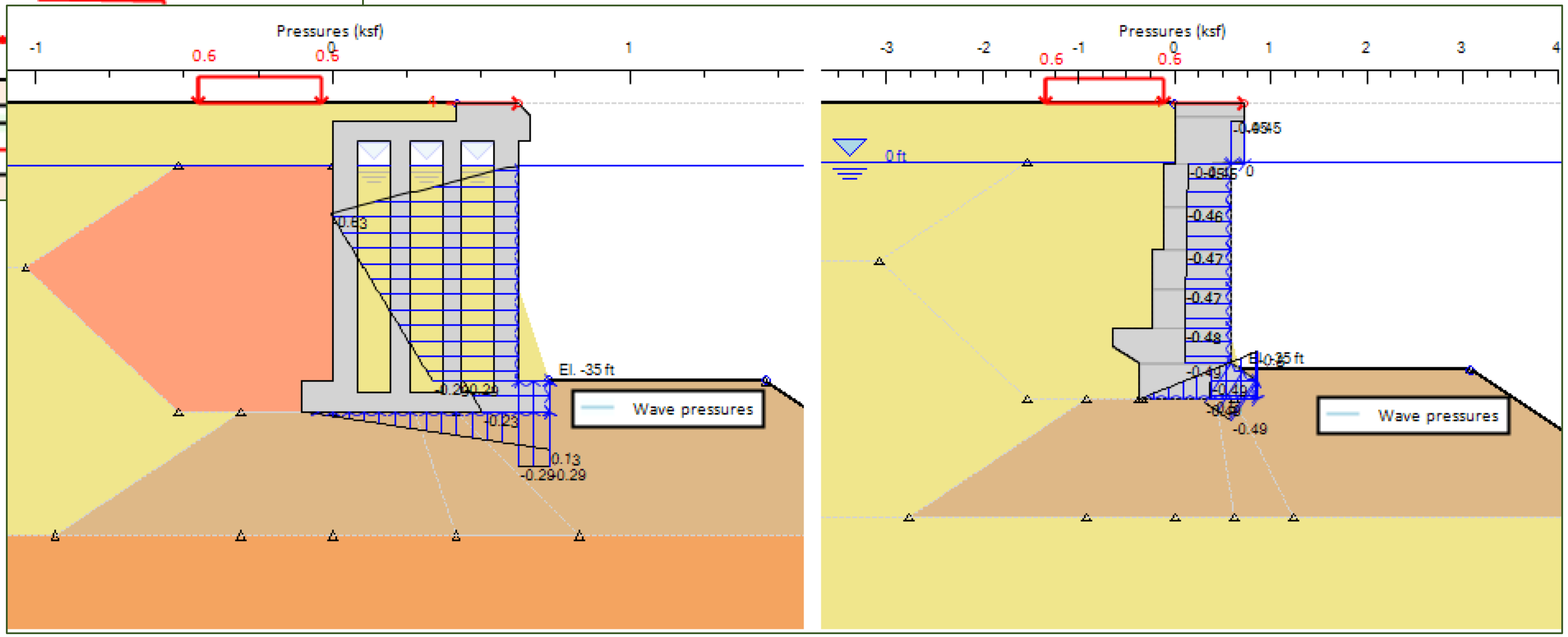
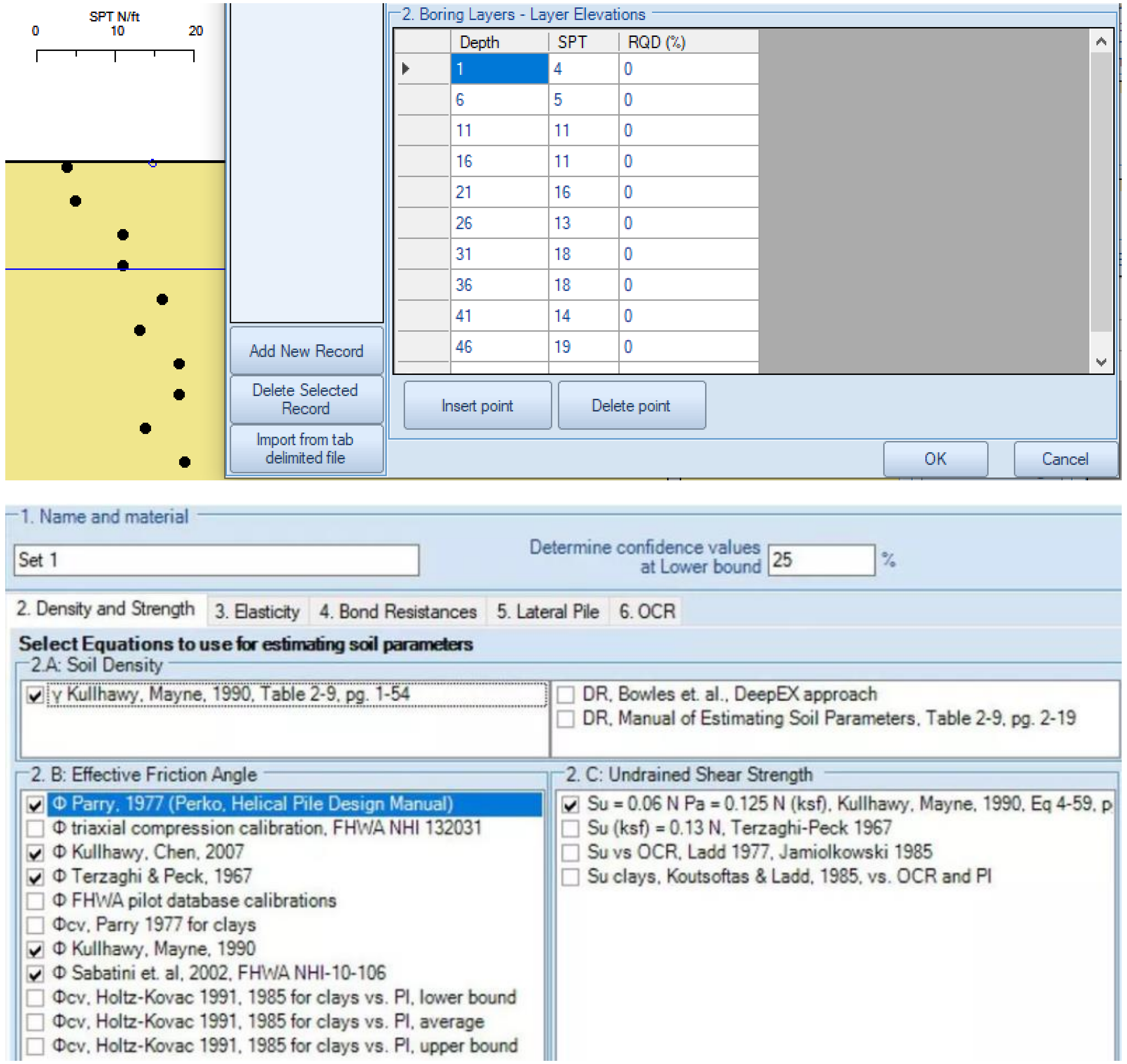
- ✓ Load combinations for British Standards 6349 Parts 1-2 (Marine Structures-Quay Walls)
- ✓ Wave pressures with Sainflou, McConnel, Proverbs
- ✓ Average overtopping volume calculations
- ✓ Block/segmental walls with individual shear resistances and densities
- ✓ Quay caisson walls (3D) with infill zones. The program can calculate the 3D weight
- ✓ Quay wall wizard - Create a model in minutes

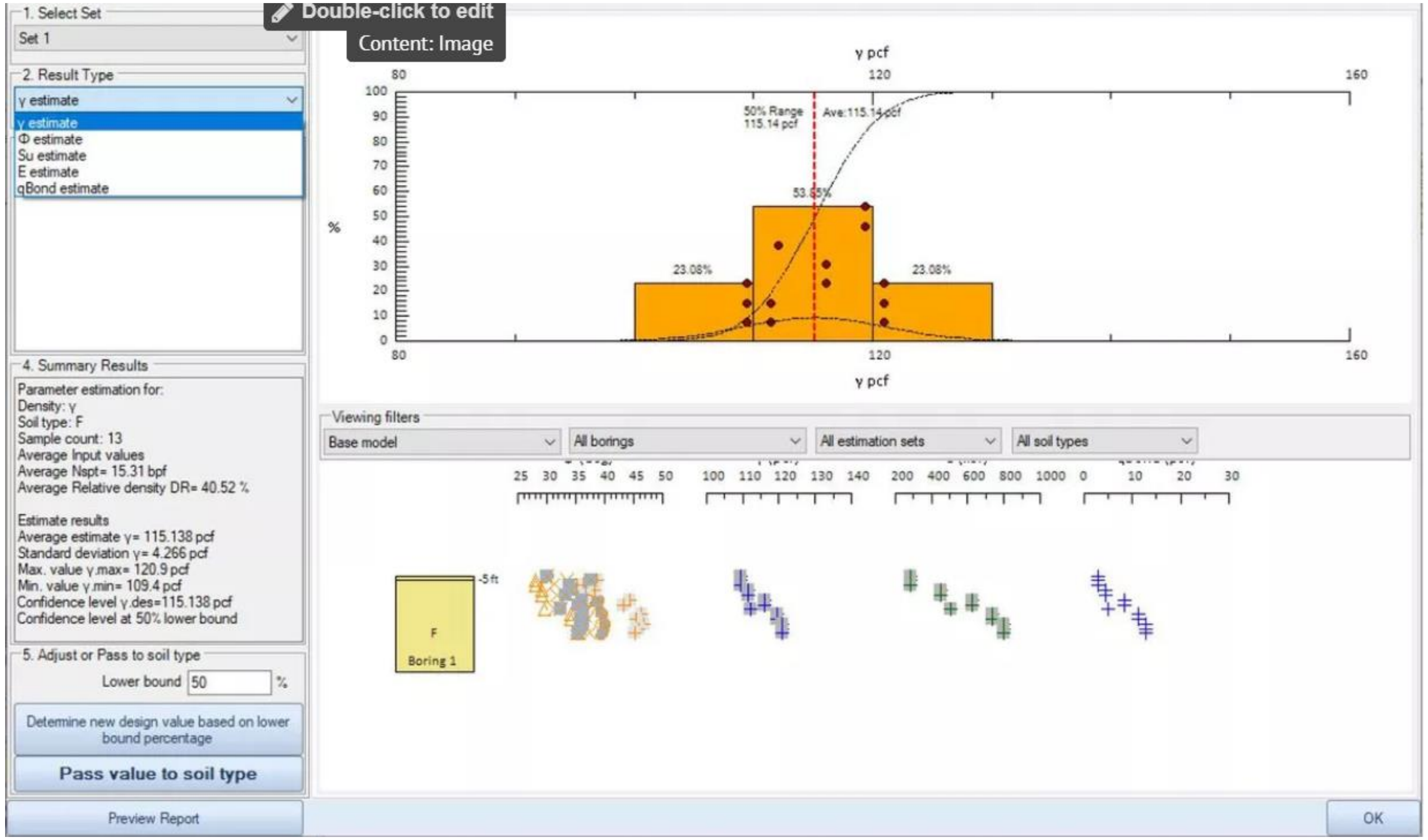




Soil Estimation - Statistical Analysis



- ✓ Estimate Soil Properties with different methods
- ✓ Review a statistical analysis of the estimated properties
- ✓ Select the project values with a high level of certainty



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Citywide Tunnels Damage Assessment

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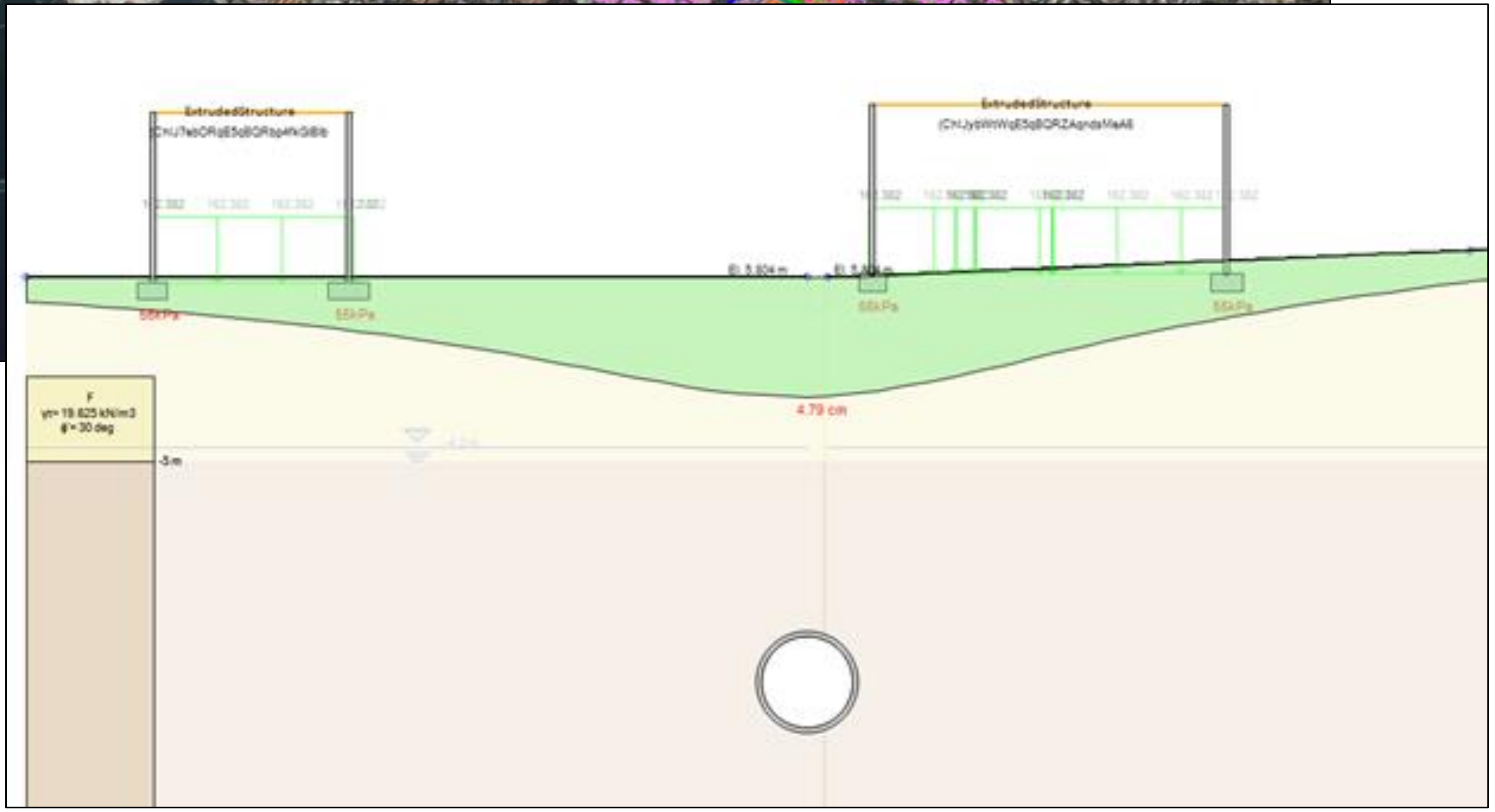
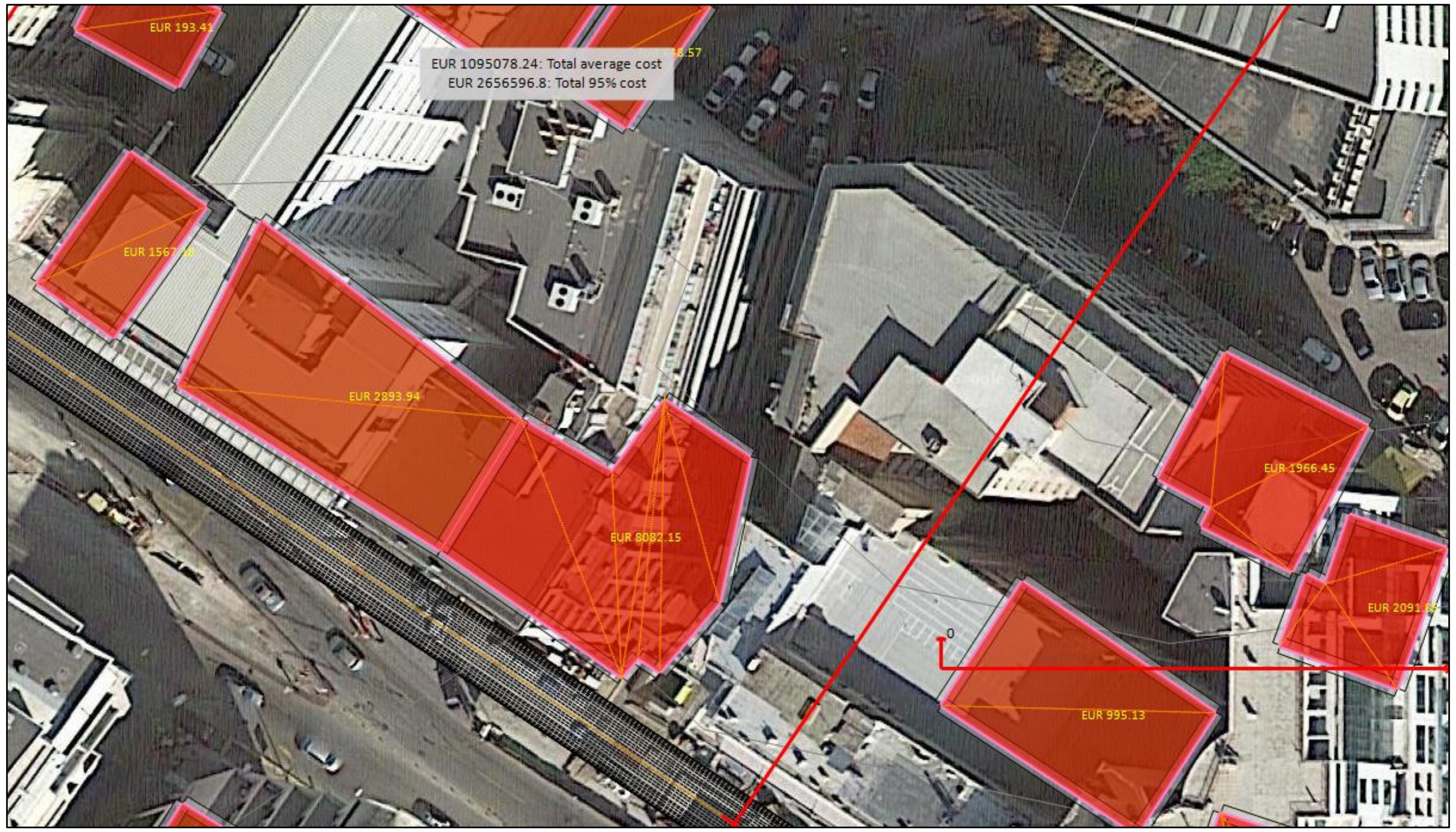
The Future is Here!

- ✓ Import your City Map with all Structures from Google
- ✓ Define your Tunnel Construction Stages and Location on the Map
- ✓ Automatically Generate 2D Cut Sections along your Tunnel
- ✓ Define your Metro Station Locations on the Map and Design Them
- ✓ Analyze the Tunnel, Calculate Settlements considering Soil Volume Loss, Consolidation and Water Drawdown
- ✓ Estimate the Damage Cost for all Imported Buildings

And more!





Thank You!

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