Design of Deep Excavations - Methods and Software Application

Presentation: Dimitrios Mamoglou, Senior Engineer, Deep Excavation LLC
mamoglou@deepexcavation.com - T: +1-206-279-3300
Deep Excavation LLC
240 W 35th Street, Suite 1004
New York, NY, 10001
USA

Websites:
www.deepexcavation.com
www.deepex.com

Contact Information:
sales@deepexcavation.com
training@deepexcavation.com

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

DeepEX
HoloDeepEX
DeepFND
HelixPile
SnailPlus
SiteMaster
PART 1: DeepEX Software Features and Analysis Methods

More information:
Click here to learn more:
DeepEX – Software Features and Capabilities
DeepEx - Shoring Design Software

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

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

www.deepexcavation.com
www.deepex.com
sales@deepexcavation.com
training@deepexcavation.com
T: +1-206-279-3300
## DeepEx Software - Wall Types

<table>
<thead>
<tr>
<th>Soldier pile and lagging walls</th>
<th>Secant pile walls</th>
<th>Tangent pile walls</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Soldier pile and lagging walls" /></td>
<td><img src="image2" alt="Secant pile walls" /></td>
<td><img src="image3" alt="Tangent pile walls" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SPTC walls</th>
<th>Diaphragm (slurry) walls</th>
<th>Sheet pile walls</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image4" alt="SPTC walls" /></td>
<td><img src="image5" alt="Diaphragm (slurry) walls" /></td>
<td><img src="image6" alt="Sheet pile walls" /></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Combined sheet pile walls</th>
<th>Box sheet pile walls</th>
<th>Custom walls</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image7" alt="Combined sheet pile walls" /></td>
<td><img src="image8" alt="Box sheet pile walls" /></td>
<td><img src="image9" alt="Custom walls" /></td>
</tr>
</tbody>
</table>
Soils and Stratigraphy in DeepEX

- Create multiple 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
Analysis Methods and Design Standards in DeepEX

Limit Equilibrium Analysis (LEM)
Non-Linear Analysis (NL) (Elastoplastic Springs)
Finite Element Analysis (FEM)

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
✓ 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.
Earth Coefficients in DeepEX Software

DeepEX Automatic Method Selection According to Project Parameters

### Active Coefficient Ka

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Horizontal Surface</th>
<th>Inclined Surface</th>
<th>Wall Friction Considered</th>
<th>Seismic Effects Applied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method</td>
<td>Rankine</td>
<td>Coulomb</td>
<td>Coulomb</td>
<td>No Effect</td>
</tr>
</tbody>
</table>

### Passive Coefficient Kp

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Horizontal Surface</th>
<th>Inclined Surface</th>
<th>Wall Friction Considered</th>
<th>Seismic Effects Applied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method</td>
<td>Rankine</td>
<td>Coulomb</td>
<td>Caquot-Kerisel</td>
<td>Lancelotta</td>
</tr>
</tbody>
</table>

![Diagram showing DeepEX Automatic Method Selection](image-url)
LEM: Soil Pressures Methods

Cantilever Excavations

Construction Stages with multiple support levels

At-Rest Pressures

Peck 1969 Pressures

FHWA Apparent Pressures

Custom Trapezoidal Pressures

Active - Passive Pressures

Two-Step Rectangular Pressures

WMATA Pressures

New York City DEP Pressures

www.deepexcavation.com
www.deepex.com

sales@deepexcavation.com
training@deepexcavation.com
T: +1-206-279-3300
Water Pressure Methods in DeepEX Software

Simplified Flow

Hydrostatic

Full Flownet Analysis

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www.deepex.com
sales@deepexcavation.com
training@deepexcavation.com
T: +1-206-279-3300
External Loads in DeepEX: Types and 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 in DeepEX Software

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 × 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
Cantilever Wall Analysis Concept

**Fixed earth method**
Balances out Moment and Shear

**Free earth method**
Balances out moment
Shear not balanced
Increase length by 1.2 to get FS 1.0
Then apply additional safety factors
Pinned supports - continuous beam

Point of zero net soil shear below subgrade.

Use point of zero shear as a virtual support.

Shear | Moments | Net loading

Reaction for embedment $F_{xb}$
Virtual support
Available resistance $R_x$

$\text{FS, passive} = \frac{R_x}{F_{xb}}$
Beam Analysis - FHWA Simple Span Approach

Pin support at excavation base, simple spans

Shear

Moments

Net loading

Reaction for embedment $F_{xb}$

Virtual support

Available resistance $R_x$

$FS_{passive} = \frac{R_x}{F_{xb}}$
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 = \( \frac{F_{resist}}{F_{drive}} \)

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www.deepex.com
sales@deepexcavation.com
training@deepexcavation.com
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Non-Linear Analysis Concept (Soil Springs)

Soil Models
- Linear elastic perfectly plastic
- Exponential
  \[ E = E_0 \left( \sigma_v + a_H \sigma_h \right)^n \]
- Subgrade modulus
- Small strain hardening
- Reloading stiffness linear 3 to 5 x loading E

Elastoplastic model
Exponential model
Finite Element Analysis in DeepEX (Additional Module)

 ✓ Moments and reactions calculated with Finite Elements
 ✓ Consider full soil-structure interaction
 ✓ Calculate surface settlements
 ✓ Design Tiedowns, Foundation Piles and Steel Columns

Soil Models:
✓ Elastoplastic Model:
✓ Exponential (Hyperbolic) Model (approximate solution)
✓ Exponential (Hyperbolic) Model (complete solution): Soil hardening model

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training@deepexcavation.com
T: +1-206-279-3300
✓ 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
PART 2: Projects Designed with DeepEX

More information: Click here to learn more: DeepEX – Project Gallery

2000+ users – more than 10000 projects worldwide!
DeepEX Software - Project - Braced Excavation

LaBrea Metro Station, Los Angeles, California, USA

- 100 ft (30.5 m) Excavation
- Soldier Piles and Lagging
- Lateral Bracing (Struts)
- Full Design with DeepEX
- 5 Stations designed and under construction

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T: +1-206-279-3300
New Tapan Zee Bridge Cofferdams, New York, USA

- $3.9 billion project
- 90x45ft (27.5x13.7m) Cofferdams
- Lateral Bracing (Struts)
- Full Design with DeepEX

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Soldier Pile Excavation Pits with Diagonal Struts and Tiebacks, Arkansas, USA

- 90 ft (27.5m) Excavation
- Soldier Piles and Lagging
- Pipe Struts
- 9 rows of Tiebacks

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training@deepexcavation.com
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Soldier Pile Excavation Pits with Diagonal Struts, Arkansas, USA

- 24 ft (7.3m) Excavation
- Soldier Piles and Lagging
- Pipe Struts
- Full Design with DeepEX

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www.deepex.com
sales@deepexcavation.com
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DeepEX Software - Project - Cofferdam

All American Canal, Imperial Irrigation District, Yuma, Arizona

- Cofferdam
- Water Wall Design
- Water Depth up to 20’ (6m)
- Sheet Pile System
- Post Tension cable Ties
- Full Design with DeepEX

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training@deepexcavation.com
T: +1-206-279-3300
PART 3: DeepEX Additional Modules and Standard Packages

More information: Click here to learn more: DeepEX – Software Versions
2D Sections and 3D Models Design - Export Holograms

- 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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training@deepexcavation.com
T: +1-206-279-3300
Perform Damage Assessment of all Buildings close to an excavation site
Review Crack widths, Damage Categories, Strains etc. for all building walls.
Export All Project Sketches to DXF

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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www.deepex.com
sales@deepexcavation.com
training@deepexcavation.com
T: +1-206-279-3300
Gravity Walls and Pile Supported Abutments

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

www.deepexcavation.com
www.deepex.com
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T: +1-206-279-3300
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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www.deepex.com
sales@deepexcavation.com
training@deepexcavation.com
T: +1-206-279-3300
# DeepEX - Standard Packages and Additional Modules

## Standard DeepEX Software Packages

<table>
<thead>
<tr>
<th>Package Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DeepEX 2D - Basic Version</strong></td>
<td>Design 2D Sections with LEM and NL Methods</td>
</tr>
<tr>
<td><strong>DeepEX 2D Plus Version</strong></td>
<td>DeepEX 2D + Export Sketches to DXF (2D)</td>
</tr>
<tr>
<td><strong>DeepEX 3D Version</strong></td>
<td>DeepEX 2D + 3D Frame Analysis + Project Cost Estimation + Export 3D Holograms</td>
</tr>
<tr>
<td><strong>DeepEX 3D Version</strong></td>
<td>DeepEX 3D + Export Sketches to DXF + 2D Section Sketches + Plan View + Elevation Views</td>
</tr>
<tr>
<td><strong>DeepEX 3D Advanced Version</strong></td>
<td>DeepEX 3D + Building Damage Assessment</td>
</tr>
</tbody>
</table>

## Available Additional Optional Modules – Expand the Standard Version Capabilities

<table>
<thead>
<tr>
<th>Module Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Finite Element Analysis</strong></td>
<td>Available to any version</td>
</tr>
<tr>
<td><strong>Gravity Walls &amp; Pile Abutments</strong></td>
<td>Available to any version</td>
</tr>
<tr>
<td><strong>Soil Estimation &amp; Statistical Analysis</strong></td>
<td>Available to any version</td>
</tr>
</tbody>
</table>

## DeepEX Licensing Options

- Single Licenses (activated in specific devices), Single USB Keys, Network USB Key Solutions
- 1 Year of full Technical Support (training, questions, file reviews) is included in any software purchase
- Optional Annual Maintenance options (after the first year)
- Discounts for Additional Licenses
- Additional Modules can be purchased and activated at any point in any software version

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